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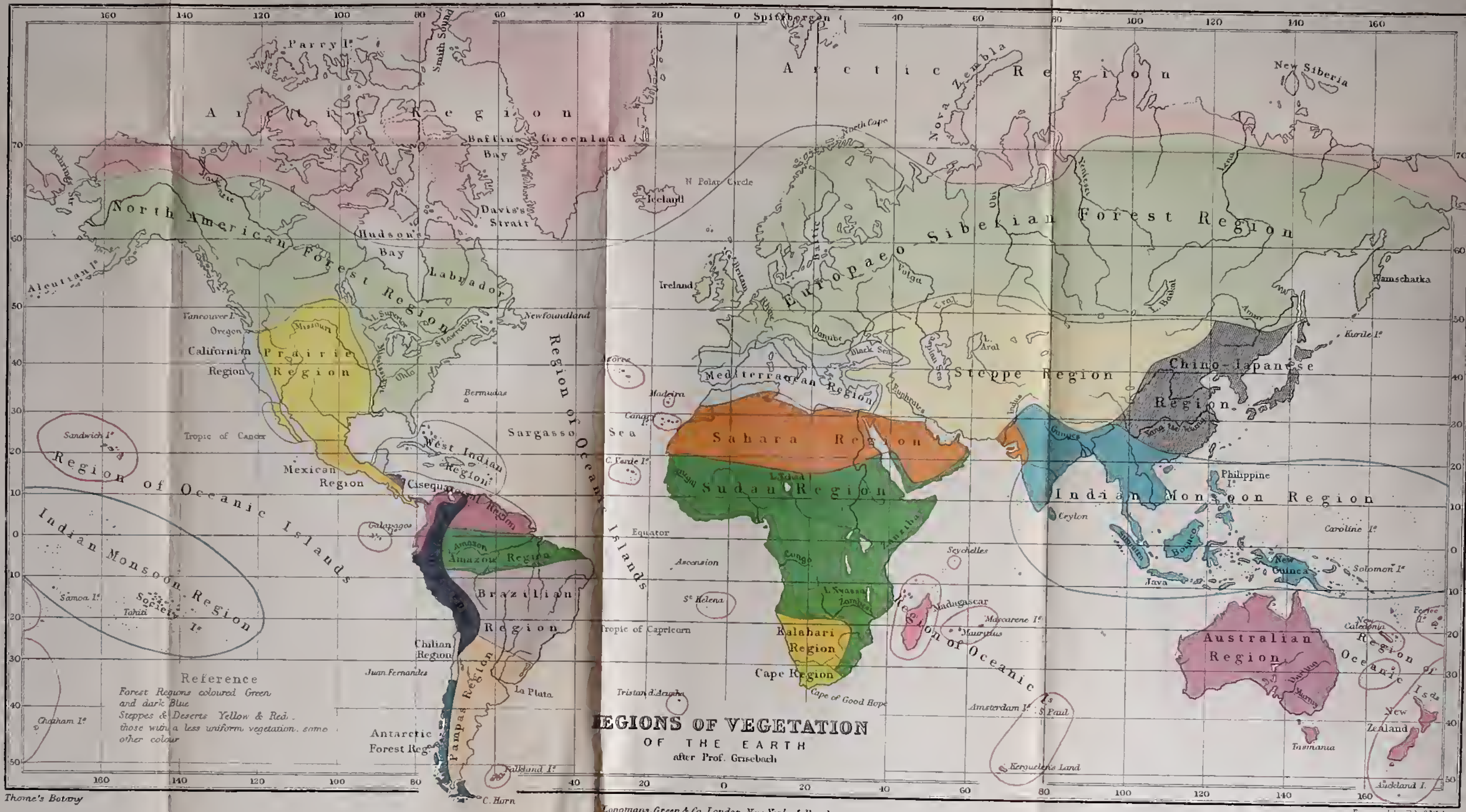
BOTANY



REGIONS OF VEGETATION
OF THE EARTH
after Prof. Grisebach

Thomé's Botany

Longmans, Green & Co. London, New York & Bombay

Engraved by Edwd Weller

TEXT-BOOK
OF
STRUCTURAL AND PHYSIOLOGICAL
BOTANY

BY

OTTO W. THOMÉ
RECTOR OF THE HIGH SCHOOL, COLOGNE
AND
ALFRED W. BENNETT, M.A., B.Sc., F.L.S.
LECTURER ON BOTANY AT ST THOMAS'S HOSPITAL

ILLUSTRATED WITH ABOUT 600 WOODCUTS AND A COLOURED MAP

EIGHTH EDITION

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PREFACE

TO

THE EIGHTH EDITION

THE period that has elapsed since the publication of the seventh edition of this Text-book has been one of great activity in botanical science. The increasing number of workers, the perfection attained in microscopical appliances, and the use of more delicate staining reagents, have helped in the solution of many difficult problems. Much light has been thrown in this way especially on the minute structure of the cell and the part played by the nucleus in cell-division; on the embryogeny of flowering plants; and on the structure and life-history of some of the lowest forms of vegetable life. In Appendix B is given a summary of all the more important observations and discoveries of the last six years, together with a definition of the new technical terms introduced into botanical science. Before passing from any section of the body of the work, the student should carefully consult the corresponding section of this Appendix. In the generally adopted classification of Flowering Plants no change of importance has been made. The classification of Flowerless Plants, especially of the lower forms, is not nearly so well established, and several important alterations have been introduced by writers of authority. But until the life-history of some of the lowest forms is more completely cleared up, it is impossible to come to a final conclusion on these points, and it has been thought better to leave this portion of the work for the present substantially unchanged.

A. W. B.

6 Park Village East:
January 1897.

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STRUCTURAL AND PHYSIOLOGICAL

BOTANY.

INTRODUCTION.

THE province of Botany, or the Natural History of the Vegetable Kingdom, is to depict the plant from as many different points of view as possible.

It is impossible to give a brief and exact definition of a plant, if such a definition is intended to include all plants. It is true that from the earliest times the numberless substances that are found on the earth have been distinguished into living or organic and lifeless or inorganic,—animals and plants being included in the former, minerals in the latter class; but it is impossible to define accurately the bounds of these three kingdoms. Whether a body has life or not is a point easily determined, since the presence of life is manifested by various capabilities, the most universally distributed of which are those for absorbing and assimilating a variety of food materials. We know also from experience that the higher and more perfectly organised animals differ from the higher plants in possessing sensibility and a power of voluntary motion. But when we descend from the higher

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animals and plants to the less perfect organisms belonging to these two kingdoms of nature, we come eventually, on the boundaries of each, to organisms so small and so imperfectly developed that it is scarcely possible to pronounce an opinion whether they are of animal or vegetable nature. The most superficial glance over the vegetable world shows us that in both the external form and internal structure of plants—the number of which has been estimated to amount to 300,000—there exists such an endless diversity that we must content ourselves with describing the forms of most common occurrence, the most important laws of their internal structure, life, and distribution, and the classification of the best known and most important plants.

Morphology, or the Comparative Anatomy of plants, embraces an acquaintance with their most important organs, and hence with their external form. By combining with this the history of development of the separate organs, *i.e.* the mode in which they are produced, we are enabled to obtain a correct comprehension of, and to describe, the different parts of a plant. By the *Anatomy* of plants we understand a knowledge of their internal structure. The *Physiology* of plants is concerned with their vital phenomena [and the different functions of the various organs]. *Botanical Geography* treats of the distribution of plants over the surface of the globe. *Palæophytology*, or Vegetable Palæontology, makes us acquainted with the remains that still exist of the vegetation of earlier geological epochs. *Classification* has to do with the distribution of plants according to their characters [or relationship to one another]. *Practical*, or *Applied Botany*, finally, explains the useful or injurious properties of plants.

In the earliest times the knowledge of plants was limited to those from which food was obtained, and to a few which afforded poisonous or curative substances, the properties of which had been ascertained by a happy or unfortunate accident, or by the observation of an animal impelled by instinct to their use. The knowledge thus laboriously gained must often have been again lost, until at length an acquaintance with medicinal plants became a speciality of the priests, and the healing art founded upon it a part of religion.

The father of medicine, as he has been termed, Hippocrates, who lived in the fifth century before Christ, extended the observations that had hitherto been made ; and we know that he enumerated upwards of 200 species which were at that time used in medicine. But it was not till the following century that a really scientific work on botany appeared, written by the celebrated tutor of Alexander the Great, Aristotle. His work is unfortunately lost ; but his ideas have come to us in the writings of his pupil Theophrastus, who described 400 or 500 different plants in their relation to agriculture, domestic economy, and medicine. At his death the new structure fell to pieces, or at all events we do not find that any further progress was made with it. This was the state of things until, in the first century after Christ, Dioscorides wrote a treatise on medicine, in which over 600 medicinal plants were described, though often briefly and insufficiently, and the elder Pliny collected what was most noteworthy from the writings of his predecessors. The position in which botany stood at that time may be understood from the naïve statement of Pliny that there were, it is true, more plants in the hedges, fields, and roadsides than those he had described, but they had no names, and were of no use. The works of Pliny and Dioscorides remained the best on the subject till the sixteenth century, and enjoyed the highest reputation. At that time German investigators arose who aroused the study of plants from its long rest, and earned therefrom the honourable title of the fathers of botany. The first of these was Otto Brunfels of Mayence (*ob.* 1534) ; other German scholars followed closely upon him, Bock (*ob.* 1554), Fuchs (*ob.* 1566), and Gessner (*ob.* 1565) ; as well as some belonging to other countries, Mathioli (*ob.* 1577), Dodonæus (*ob.* 1585), Lobelius (*ob.* 1616), and Clusius (*ob.* 1609). But no one of these made any great advance; for none of them went beyond a more or less careful description of different plants.

Cæsalpinius (*ob.* 1603) was the first to devote himself to a systematic classification of plants. He derived his principles mainly from the characters of the fruit and from the position of the perianth in reference to the pistil; but his primary division of the vegetable kingdom was into woody and herbaceous plants. His example was followed by others, and the science received an ever-increasing impetus, directed by such men as Tabernæmontanus (*ob.* 1590), Alpinus (*ob.* 1616), and Camerarius (*ob.* 1721), an impetus which was greatly assisted by the great store of botanical material derived from travels in the East and in America. But there were no means of comparing these fresh discoveries with one another, in consequence of a want of correspondence in the names given to the same plant by different investigators. The brothers John and Caspar Bauhin (*ob.* 1613 and 1624) were the first to endeavour to overcome this difficulty. From this time the number of botanists increased so greatly that we can mention only those who introduced new and influential ideas.

The originator of the Latin botanical nomenclature was Jung (*ob.* 1657), rector of the gymnasium at Hamburgh. Soon afterwards, in 1700, Tournefort (*ob.* 1708) propounded a new system, and was the first to classify plants into strictly defined genera. A year before his death, the great reformer of botany, the Swede Carl von Linné (Linnæus, *ob.* 1778), was born. It was he who first raised botany to the rank which it should have attained long before, of an edifice resting on a firm foundation; for to him we owe the first system of nomenclature and description of a truly scientific character. But this was not all; for Linnæus propounded the celebrated system that bears his name, which has indeed since been replaced by others of a much more natural character, but which is unequalled in practical value if the purpose is simply to name any given plant, or to assign its position in the system to any newly-discovered species. The Linnean system is an artificial one, since it is not founded on a combination of all, nor even of several, characters of a plant, but takes into account only single characters as the primary principle of classification. There were therefore necessarily opponents of the system. The first to propose in its place a natural system was the French botanist A. L. de Jussieu (*ob.* 1836), who took as his starting-point the presence and the structure of the embryo. He was shortly followed by A. P. De Candolle (*ob.* 1841) and Endlicher (*ob.* 1849) ; the foundation of the primary classification being with the former anatomical structure, with the latter the mode of growth. The efforts to construct better systems are not yet brought to a conclusion ; and we cannot yet see their end. In the meantime botanists are vigorously at work in completing the botanical material, whether by the compilation of ' Floras ' which treat of the plants of particular districts, or by travels through districts hitherto unknown or not yet sufficiently explored.

If we now attempt to sketch in a few lines the history of the development of the remaining departments of botanical science ;—it appears, as might be expected, that the study of the anatomy of plants came into existence shortly after the discovery of the art of manufacturing magnifying lenses. The English botanist Grew (*ob.* 1711) and Malpighi of Bologna (*ob.* 1694) must be considered as the true founders of this study. After the ground had been successfully broken by their researches, it was almost entirely neglected during the eighteenth century, and the investigation has only recently been again resumed, and this branch of botany carried to a truly remarkable perfection by our contemporaries A. Braun (*ob.* 1877), Göppert (*ob.* 1884), Von Mohl (*ob.* 1872), Schacht (*ob.* 1864), Schleiden (*ob.* 1882), Unger (*ob.* 1870), and many others.

While during the eighteenth century the study of anatomy lay dormant, especial interest was excited by problems of physiology, and a great many pioneers of science occupied themselves with their solution; among whom may be especially mentioned Hales (*ob.* 1761), Bonnet (*ob.* 1793), Duhamel (*ob.* 1781), Priestley (*ob.* 1804), and Ingenhousz (*ob.* 1799).

Reference must not be omitted to the fact that the poet Goethe established the science of morphology on a firmer basis by his writings; and that it was reserved for Alexander von Humboldt (*ob.* 1859), at the commencement of this century, to put the study of Botanical Geography into a scientific shape. Palæophytology was advanced especially by Brongniart (*ob.* 1876), Unger, Göppert, &c. We must, however, refrain from entering into detail with regard to the labours of our own contemporaries; and will only name the most eminent recent German botanists who have not hitherto been mentioned, *viz.*, among others, De Bary, Caspary, Dippel, Hanstein (*ob.* 1880), Hartig, Hildebrand, Hoffmann, Hofmeister (*ob.* 1877), Karsten, Von Martius (*ob.* 1868), Milde (*ob.* 1871), Nägeli, Pringsheim, Rabenhorst, Sachs, [Strasburger], and Schwendener.[1]

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[1] [The dates, which do not in all cases agree exactly with those stated by the author, are given on the authority of Sachs, in his 'Geschichte der Botanik.' As the author has given most prominence to German botanists, it may be allowed to name the following in addition, as worthy of mention. Among systematists Ray (*ob.* 1705) holds an important place; and the present comparative perfection of our system of classification is due largely to Lindley (*ob.* 1865) and Bentham (*ob.* 1884). Vegetable anatomy owes much to the observations and publications of A. St. Hilaire (*ob.* 1853), Robert Brown (*ob.* 1858), Sir. W. Hooker (*ob.* 1865), Payer, Cohn, Sir J. D. Hooker, Asa Gray, and Berkeley; physiology to C. C. Sprengel (*ob.* 1816), Boussingault, and Darwin (*ob.* 1882).—Ed.]

CHAPTER I.

THE CELL AS AN INDIVIDUAL.

If a small quantity of the green mould (*Penicillium glaucum*) which commonly appears on articles of food that have been kept for a few days, is examined under the microscope, it is found to present somewhat the appearance of a minute tree (Fig. 1). The stem is simple, but bears at its summit a number of branches resembling strings of beads. Each of these strings easily breaks up into its separate members; and each of these members has the form of a tiny spherical bladder with a delicate coat, enclosing contents of a peculiar composition. All the branches and the main stem consist of similar bodies, differing only in their greater length; and these bodies are termed *cells*. In the example which we have chosen the individual cells are connected with one another only like beads on a necklace; but a close examination shows us that all parts of all plants are formed of cells, or are composed of structures which have themselves been formed out of cells. Examples of this are furnished by the ripe but not too succulent flesh of fruits such as the

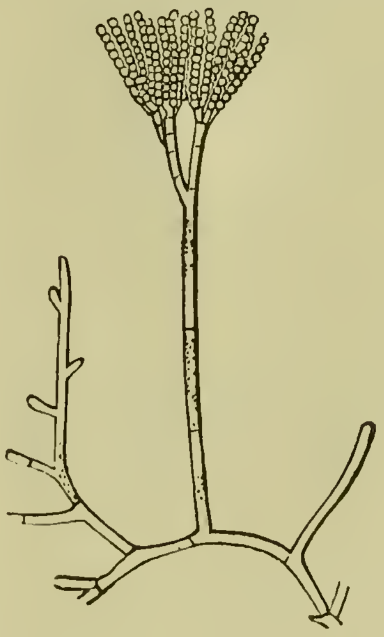

Fig. 1.—Green mould, *Penicillium glaucum*. (× about 80 diam.)

apple, slices of leaves which are not too delicate, such as the cabbage, etc. Since therefore, at least at a certain period of their existence, all plants consist of one or more cells, these are termed the *elementary organs* of plants. There is only this one kind of elementary organ, which may vary greatly in its form and behaviour, but is always the same in its essential nature.

Until recently the essential constituents of the cell were considered to be a more or less firm *cell-wall* (Fig. 2 *a*), differing in its chemical composition from the contents of the cell, a *cell-fluid* enclosed by it, and the *nucleus*, *c*, occurring in the latter. The cell-fluid was again divided into two principal elements, the watery *cell-sap*, and the mucilaginous semi-fluid *protoplasm*, *b*, in the clear transparent hyaline substance of which are imbedded a larger or smaller number of granules, generally of very small size. Some even went so far as to consider the cell-wall the most important element, and the term cell was applied even to the walls of perfectly dead cells which had lost the whole of their contents. But since cells were subsequently observed in which, at least for a certain period of their existence, such a firm wall, differing chemically from their contents, was wanting, and since also there are cells in which a nucleus is never found, it became necessary to modify the idea of a cell, and the only essential constituent is now held to be the protoplasm. In the vegetable kingdom this protoplasm rarely remains permanently uninvested by a firm envelope, but is usually sooner or later enclosed in an elastic more or less solid membrane, the substance of which

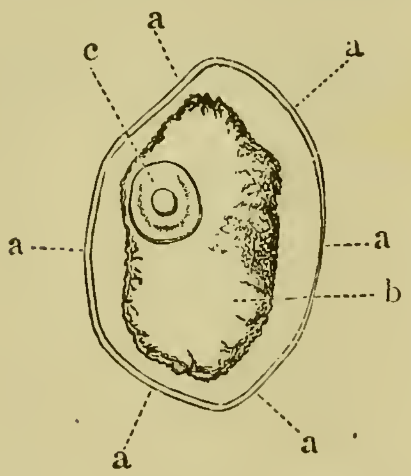

FIG. 2.—A cell from the root of the lizard-orchis, *Orchis hircina*; *a* the cell-wall, consisting of cellulose; *b* the protoplasm contracted by alcohol; *c* the nucleus with a nucleolus. (× 200.)

it secretes out of itself. Only those cells are in a living state which still contain protoplasm; such alone can grow, produce new chemical combinations, and, under favourable circumstances, give rise to new cells. Cells destitute of protoplasm are of service to the plant only by their hardness, their power of attracting water, and their form, or as protecting envelopes.

Every mass of protoplasm, whether free or enclosed in a cell-wall, has a definite external boundary, where a layer of it is distinguished from the internal portion by the absence of the imbedded granules, and by its greater transparency. This layer, called the *parietal* or *primordial utricle*, is not sharply defined on its inside, but passes gradually into the granular and less dense internal mass; it is thin, being only very rarely of a measurable thickness. The protoplasm which is contained within a cell-wall does not generally entirely fill up the cavity, but more often occurs as a delicate parietal layer lining the cell-wall on the inside, and surrounding the hollow cavity filled with watery cell-sap.

The protoplasm is a compound of different organic substances, among which albuminous (nitrogenous) are never absent, and usually constitute the bulk of it. It therefore easily coagulates, often merely by the addition of water; and this is especially the case in the cells of those plants which do not live in water. It nevertheless contains abundance of water, and is usually very turgescent; *i.e.* it possesses in a high degree the power of absorbing water between its most minute particles, and swelling up in consequence somewhat in the manner of a gum. This power of absorbing water is, however, limited; as soon as it exceeds a certain amount, a watery fluid is exuded in drops in the interior of the mass of protoplasm, forming cavities or *vacuoles* within it. The protoplasm can combine with water only slowly and not in any desired proportion; and, even when most strongly magnified, presents the appearance of being separated by sharp outlines from the watery fluid which surrounds it, or which fills up the cavities in its interior. Water passes easily through a layer of protoplasm; but the latter offers, in the living state, a strong resistance to substances, such as colouring matters or salts, dissolved in water, which is generally overcome only by such injuries as destroy the life of the cell.

Every formation of new cells which can be submitted to observation begins with a change in the protoplasm, the true body of the cell; and this substance is consequently the origin of all new development. It cannot therefore be destitute of structure, but must be already organised;

and it must be simply the imperfection of our microscopes which prevents us from recognizing that organisation which is a necessary accompaniment of all vital phenomena. One of the most important of these phenomena is its *motility* or power of movement. A continuous, even though generally extremely slow and imperceptible, movement of the minute particles is inseparable from the idea of life ; and that movements of this kind must be especially energetic in the case of protoplasm may be inferred from its extreme importance to the life of the plant ; although they are usually not visible. Perceptible movements are especially clearly seen in some of those cells —termed *primordial cells*—which are not enclosed in a firm cell-wall ; the movements of the protoplasm being often so vigorous in them that the cells are propelled to a considerable distance from their original position, and present to the beginner the appearance of animal organisms endowed with voluntary power of motion. Instances of this are furnished by the 'swarming' motion of swarmspores and antherozoids, the amœba-like movements of the Myxomycetes, &c. Protoplasm which is enclosed in a cell-wall has ordinarily no power of escaping from its envelope; but even when so enclosed the microscope shows a 'streaming' of the protoplasm in all young living cells. The course of the current is usually only along the wall, and in simple spiral or reticulate lines, and is then termed *rotation*, as in *Chara* and *Vallisneria* (Fig. 40, p. 25); when, as in the filaments of *Tradescantia*, it passes in threads and bands transversely through the cell-sap, it is called *circulation* (Fig. 3). The currents are apparently irregular, now advancing, now retreating, sometimes suddenly arrested and commencing again with increased rapidity, and again forming for themselves new paths through the cell-sap.

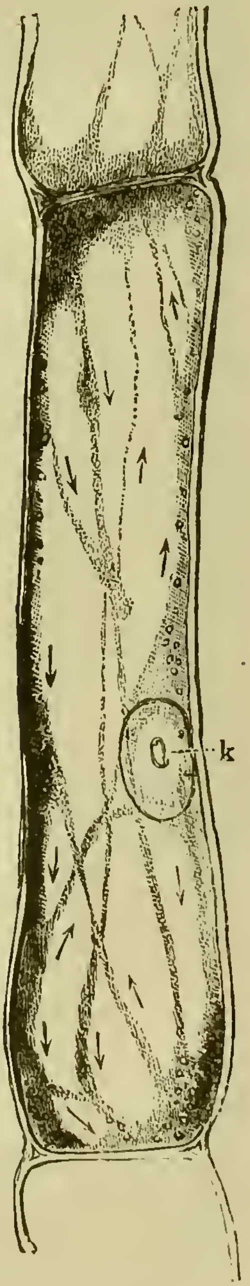

FIG. 3.—Circulation of protoplasm in an elongated cell of the celandine ; *k* the nucleus with a nucleolus. The arrows indicate the direction of the currents. (× 460.)

Possibly in all, at all events in the immense majority of cells, is a *nucleus* or cytoblast. In the dead state the nucleus is a spherical or flattened lenticular body of from 0·004 to 0·04 mm. diameter; they often possess a pellicle, and contain one or more *nucleoli* (see Figs. 2 and 3). In the living condition they are often very difficult to recognise, but appear to be larger than when dead, and of variable irregularly jagged form. [Although, as a rule, each perfect cell contains only a single nucleus, examples of *multinucleated cells* are not uncommon, as in the embryo-sac and suspensor of Leguminosæ, and in the Siphonocladaceæ, a group of Algæ with remarkably large branched cells.]

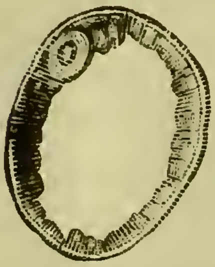

Fig. 4. — Spherical cell from the flesh of the peach. (× 370.)

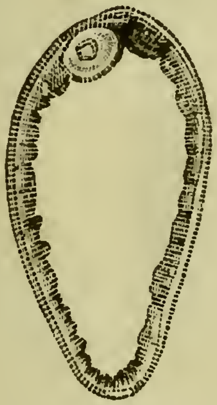

Fig. 5. — Ellipsoidal cell from the flesh of the peach. (× 370.)

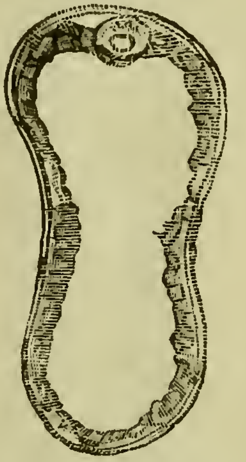

Fig. 6. — Hour-glass shaped cell from the flesh of the peach. (× 370.)

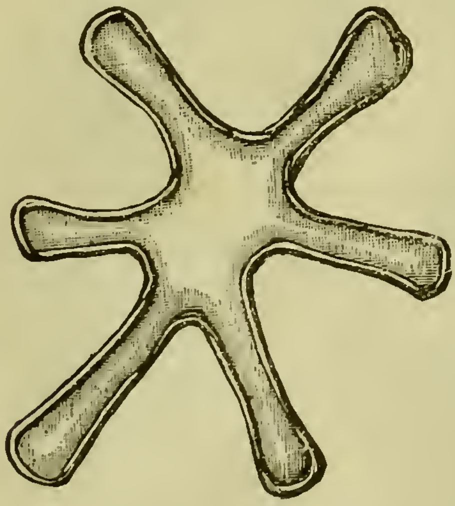

Fig. 7.—Stellate cell from the horizontal septum of the air-passages of the flowering rush, *Butomus umbellatus.* (× 780.)

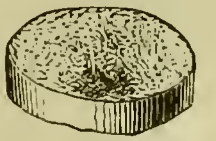

Fig. 8.—Disc-shaped cell: a unicellular Alga, *Coscinodiscus.* (× 390.)

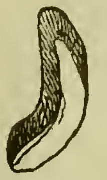

Fig. 9.—Crescent-shaped cell of a stoma (guard-cell).

The form and size of the naked cell (without cell wall) are very various, in consequence of the constantly changing motion of the protoplasm. In those which are enclosed in a firm wall or membrane of cellulose, the cell-wall determines the size and form of the cell. Although cells vary relatively so greatly in size, they are generally very minute even in their mature state, being scarcely visible to the naked eye, or usually altogether invisible. The unicellular *Micrococcus* (Fig. 380, p. 245), for example, is from 0·001 to 0·002 mm. broad and long; the diameter of pollen-grains varies between 0·1 and 0·0075 mm., [while the pollen-tubes may attain a length of 1 or 2 inches]. There are, however, cells of a larger size in the Characeæ; thus *Nitella* has cylindrical cells more than 50 mm. long, and 1 mm. in diameter; [and in some groups of Algæ, as the Vaucheriaceæ and Siphonocladaceæ, the individual consists of a single much-branched cell many centimetres in length]. The walls which bound the cells are seldom flat, but usually curved, of perfectly spherical, cylindrical, or even branched and arborescent form. The most common forms of cells are—spherical (Fig. 4);

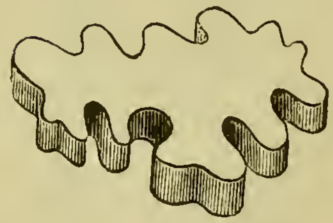

FIG. 10.—Tabular cell from the epidermis of *Callitriche.*

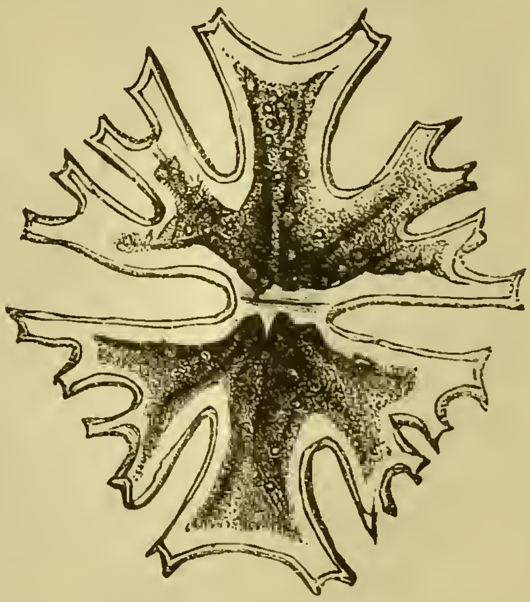

FIG. 11.—Irregularly stellate cell: a desmid, *Euastrum crux-nelitensis.* (× 400.)

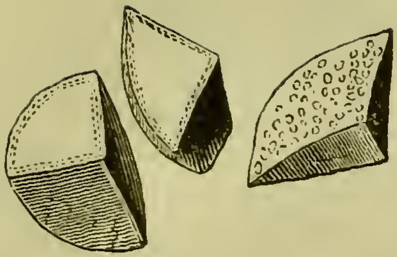

FIG. 12.—Tetrahedral cells: spore of a fern in various positions (greatly magnified).

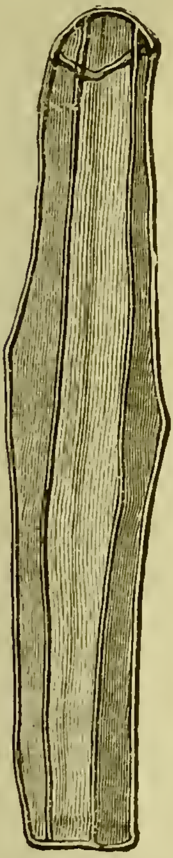

FIG. 13.—Prismatic cell from the bast-parenchyma of a *Begonia*. (× 370).

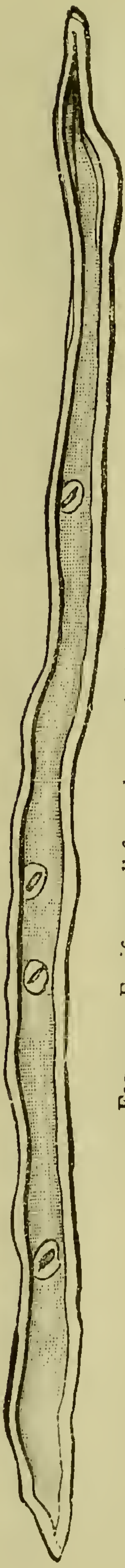

FIG. 14.—Fusiform cell from the wood of the spruce-fir, with bordered pits. (× 125.)

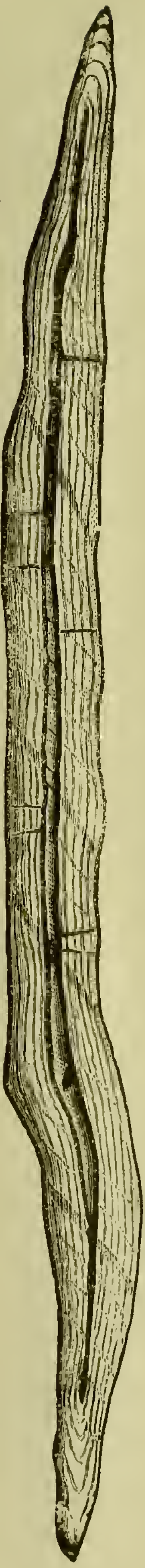

FIG. 15.—Fusiform bast-fibre of the larch. (× 125.)

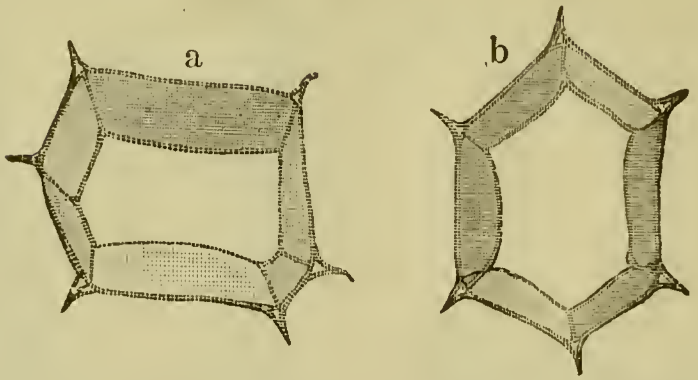

FIG. 16.—Polyhedral cell from the pith of *Acacia lophantha*; *a* seen in transverse, *b* in longitudinal section. (× 370.)

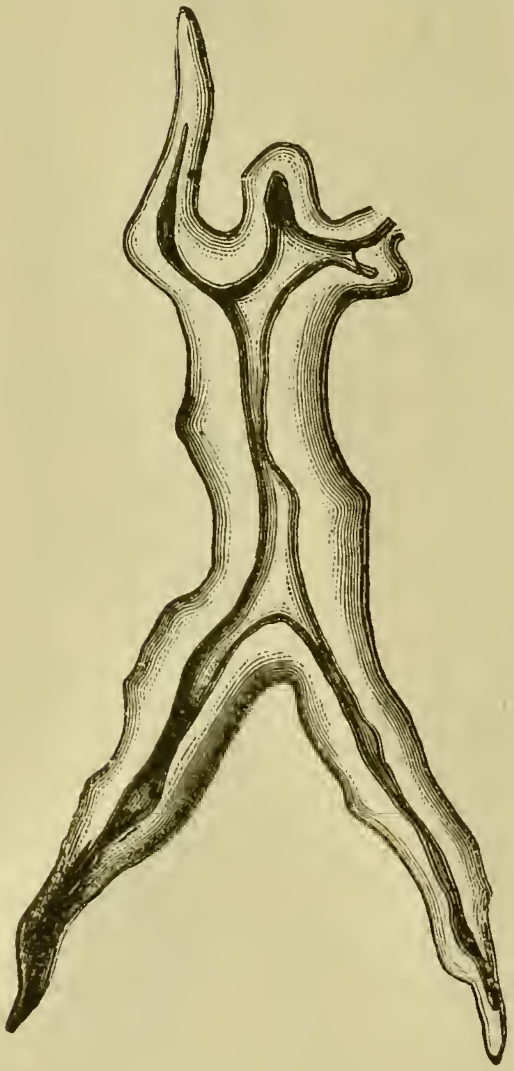

FIG. 17.—Branched bast-cell of the larch. (× 200.)

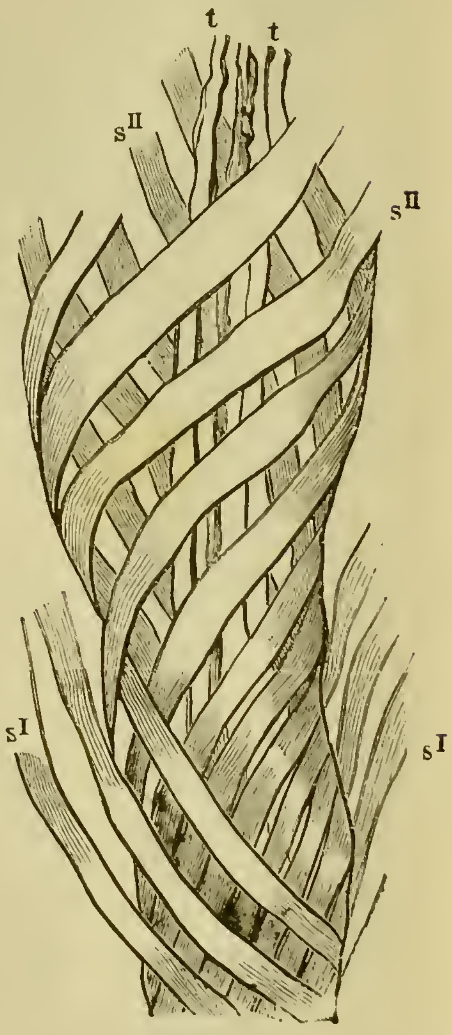

FIG. 18.—Part of a bast-cell of the oleander, treated with ammoniacal cupric oxide: $s' s'$ spiral bands of the outer shell; s'' spiral bands of the inner shell; the former nearly dissolved, the latter partially; *t* third innermost mass of layers. (× 800.)

ellipsoidal (Fig. 5); hour-glass-shaped (Fig. 6); stellate (Figs. 7 and 11); disc-shaped (Fig. 8); crescent-shaped (Fig. 9); tabular (Fig. 10); tetrahedral (Fig. 12); prismatic (Fig. 13); fusiform (Figs. 14, 15); polyhedral (Fig. 16); irregularly branched (Fig. 17).

All these forms, to which many others might be added, are produced from cells which are originally more or less spherical, according as the pressure to which they are subject from the adjacent cells is greater or less, and according as the vigour of their growth on all sides is more or less uniform. It is by far most probable that the growth of the cell-wall, when once formed, takes place solely by *intussusception*, that is, by the intercalation of fresh particles of cellulose among those already in existence. This process is the essential element of those long-enduring changes of a physical and chemical character to which the cell-wall is subject during its growth, causing it to be of essentially different nature from the shell of a mussel, on the inner side of which new layers are being constantly deposited. The wall serves not only for the external protection of the cell, but is most intimately connected with its life; so that even when the cell has long ceased to exercise an active influence on the life of the plant by the formation of new cells or by the secretion of special substances within it, other changes are still proceeding in the cell-wall, which may often be perceived even by the naked eye; as in ebony-wood, the innermost layers or 'duramen' of which become of a darker colour than the 'alburnum' or layers of wood which lie nearest to the bark.

The cell-wall appears at first as a thin, apparently structureless membrane (the *primary cell-wall*); in the course of its growth, however, several layers, *thickening-layers*, are apparently deposited at an early period on the inside. Although under the microscope these layers seem very clearly defined from one another and from the primary cell-wall, such a definition does not actually always exist (see Figs. 19-21). The fact that the cell-wall appears to consist of several layers depends on the unequal density of the separate lamellæ; and this can be explained by an unequal absorption of water, the layers appearing as if quite unstratified when dry. Always less evident than the thickening-layers, there can be perceived on the cell-wall delicate spiral, longitudinal, and transverse striations (Fig. 26, p. 18); and this *striation* is also, as a rule, only the result of an unequal absorption of water. The *formation of shells*, in which the cell-wall is split up into two or more strata of different chemical and physical properties, must be clearly distinguished from the thickening-layers. Each of these

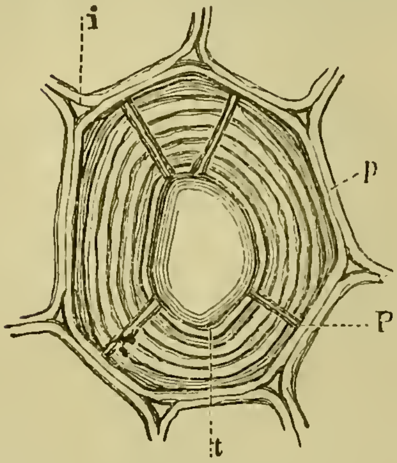

Fig. 19.—Transverse section of a cell of the pith of *Clematis vitalba*; *p* primary cell-wall; *t* innermost thickening-layer; P pore-canal; *i* intercellular space. (× 780.)

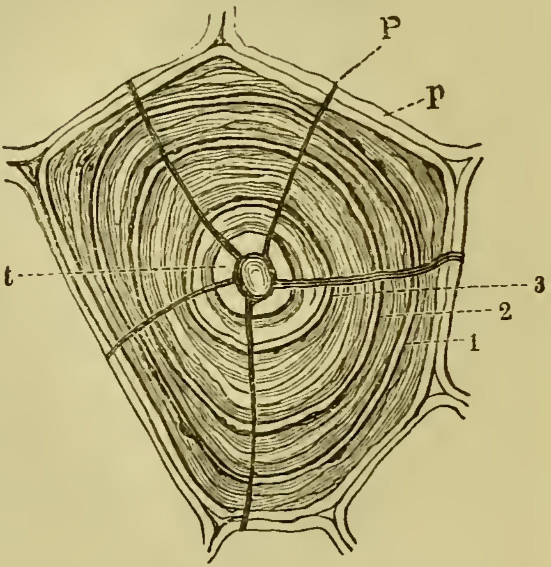

Fig. 20.—Bast-cell from the stem of *Urania guyanensis*, with several shells (1, 2, 3, *t*) and simple pore-canals P; *p* primary cell-wall of an adjacent cell. (× 780.)

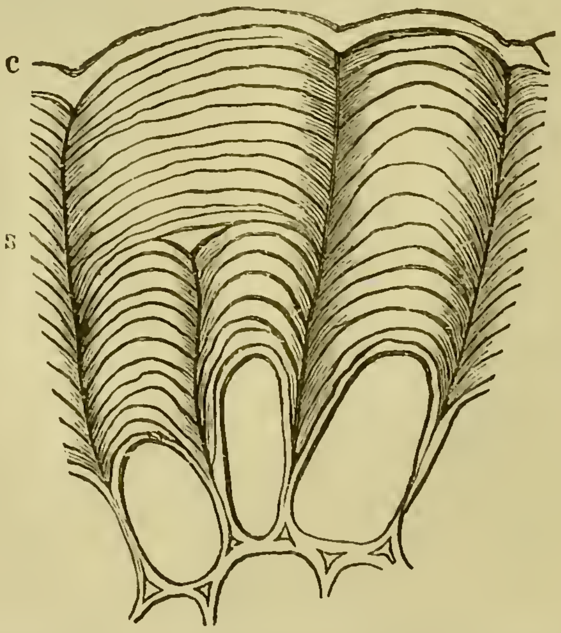

Fig. 21.—Longitudinal section through several cells of the epidermis of the mistletoe thickened on one side only; *s* thickening-layers; *c* cuticle. (× 660.)

shells corresponds to a complete system consisting of a number of thickening-layers, and may manifest the striation already described. This formation is peculiar to more strongly thickened cells, and can usually be detected only by the application of powerful chemical reagents, which cause the shell to split up by fissures previously existing into

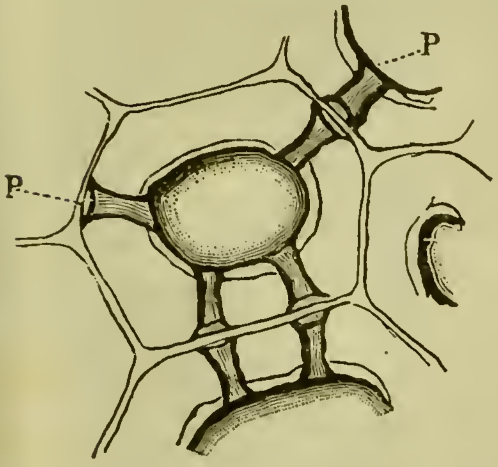

FIG. 22.—Entire cell, with parts of contiguous cells, from the endosperm (albumen) of the seed of the vegetable ivory, *Phytelephas*, with pore-canals (P P) somewhat widened at the base. (× 370.)

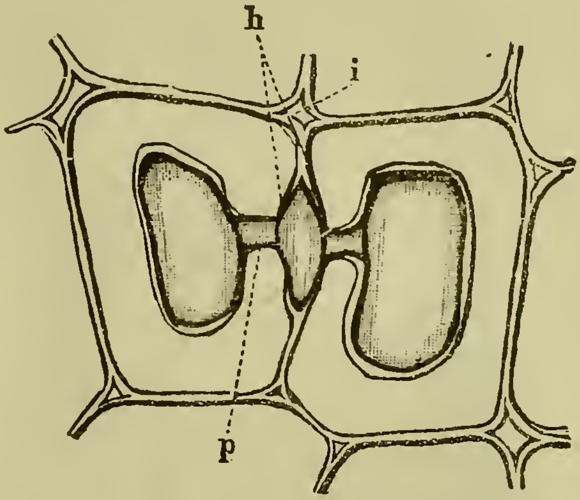

FIG. 23.—Two cells from the wood of the Scotch fir in transverse section, each with a pore *p*, widened at its base. By the disappearance of the original cell-wall the two widenings have united to form the 'border,' *h* ; *i* intercellular space. (× 660.)

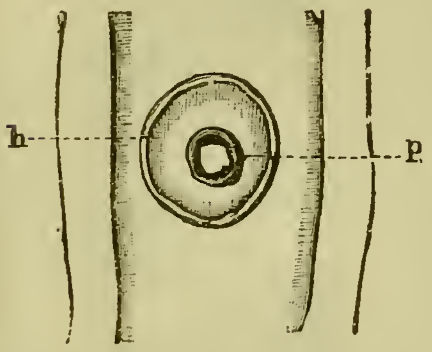

FIG. 24.—Part of a wood-cell from the Scotch fir seen vertically (*cf.* Fig. 27) ; *p* open pore ; *h* its border, which has the appearance, seen from above, of a saucer-shaped depression with a central orifice *p*. (× 660.)

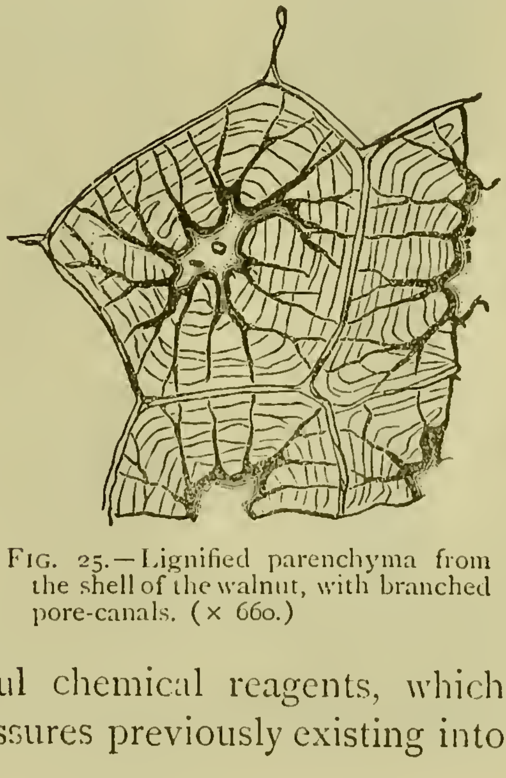

FIG. 25.—Lignified parenchyma from the shell of the walnut, with branched pore-canals. (× 660.)

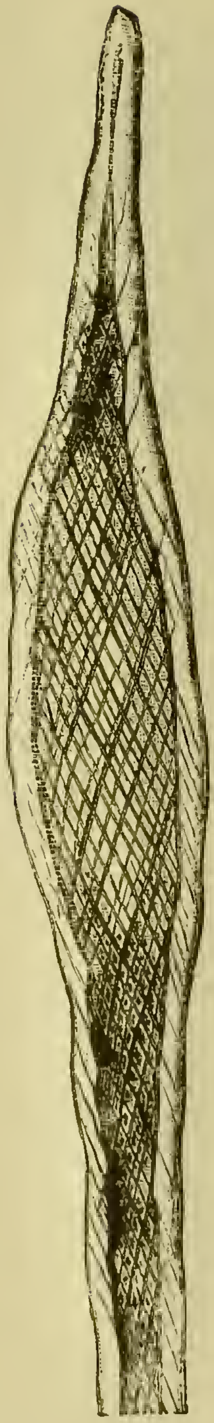

FIG. 26.—Bast-cell of *Cynanchum vincetoxicum*, with intercrossing spiral striations. (× 370.)

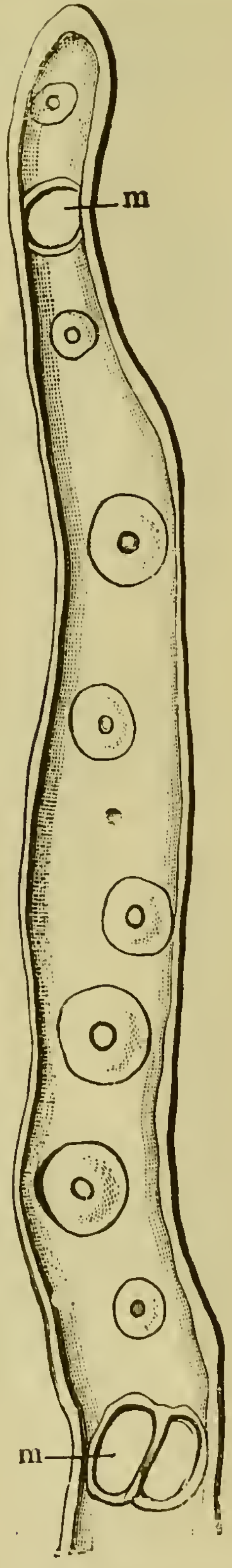

FIG. 27.—Wood-cell (tracheïd) of the Scotch fir, with bordered pits; *m m* pores connecting the cells of the wood with those of the medullary rays. (× 400.)

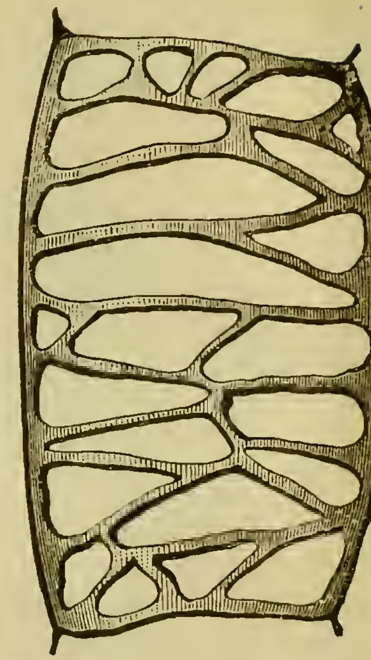

FIG. 28.—Reticulately thickened cell of the touch-me-not, *Impatiens noli-me-tangere*. (× 370.)

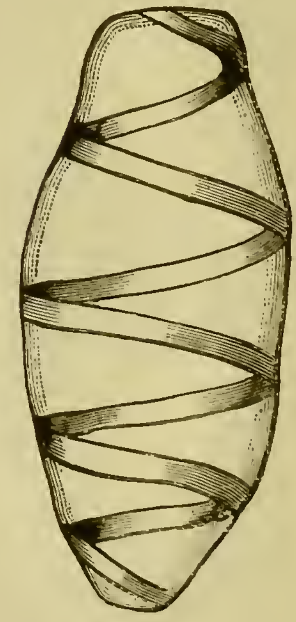

FIG. 29.—A spiral cell from a cactus, *Opuntia Tuna*, with strongly thickened spiral band. (× 400.)

several spiral bands (Fig. 18, p. 14). The thickening-layers often increase so considerably that the space enclosed by the cell-wall, the *cell-cavity*, almost entirely disappears (Fig. 20).

The increase of the cell-wall in thickness is almost invariably uniform only in its earliest stage; a want of uniformity very soon sets in at various spots. This is especially manifested at the corners and edges, the cell-cavity being always more or less rounded off; but it subsequently often takes place only on one side (Fig. 21), or so slightly at particular spots that *pitted* or *pore-canals* are formed at those spots. These are sometimes simple (Figs. 19, 20), sometimes branched (Fig. 25). The canals from adjoining cells constantly meet; sometimes they are widened at their base into *bordered pits* (Fig. 22); and the membrane between these frequently disappears, so that cells become thus actually perforated (Figs. 23, 24). According to the development of

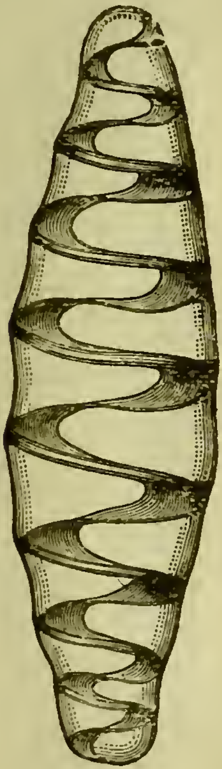

FIG. 30.—A spiral cell from a cactus, *Mamillaria*, with flattened spiral band. (× 400.)

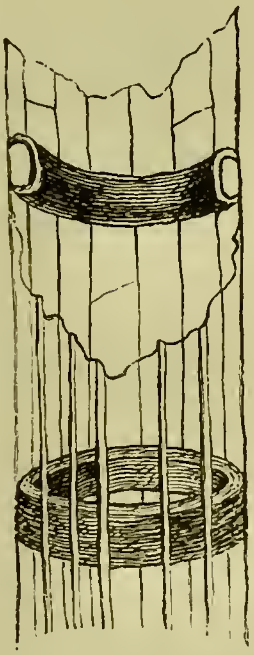

FIG. 31.—Piece of an annular cell from the stem of the Turkish wheat; the edges of contiguous cells are visible on the cell-wall. (× 500.)

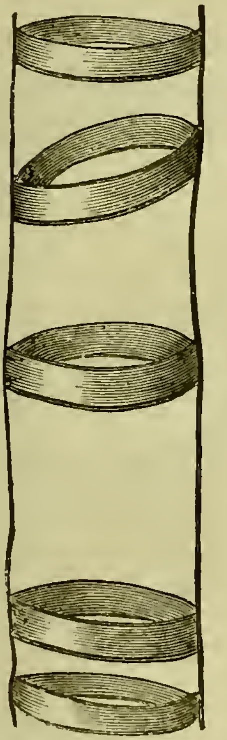

FIG. 32.—Annular cell from *Arundo donax*, with strongly thickened rings placed at different distances and different angles. (× 400.)

the pits or of the thickening-layers we distinguish between *pitted cells* (Fig. 27), *reticulated cells* (Fig. 28), *spiral cells* (Figs. 29, 30), *annular cells* (Figs. 31–34), and *scalariform* (ladder-like) *cells* (Fig. 36). A *slerenchymatous cell* (Fig. 25) is one in which the cell-wall has become uniformly very greatly thickened and hardened.

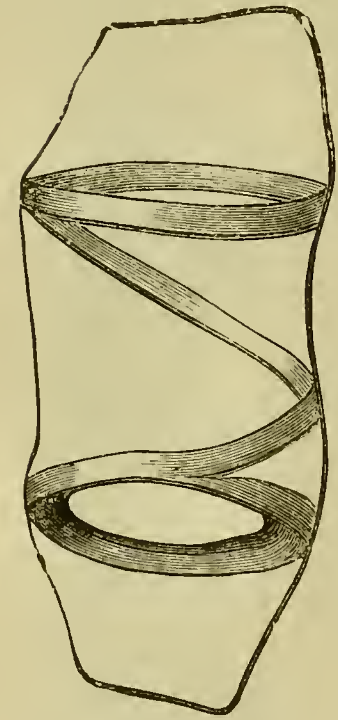

Fig. 33.—Annular cell from an *Opuntia* with rings passing over into a spiral band. (× 400.)

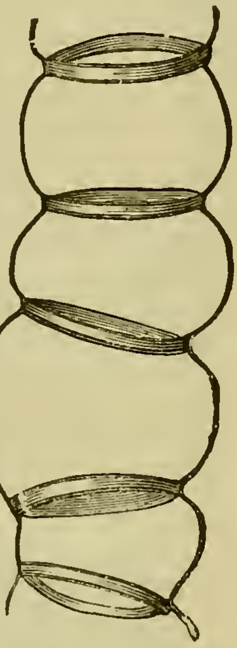

Fig. 34.—Annular cell from the balsam, *Balsamina hortensis*, with the primary cell-wall bulging into a barrel-shape between the rings. (× 400.)

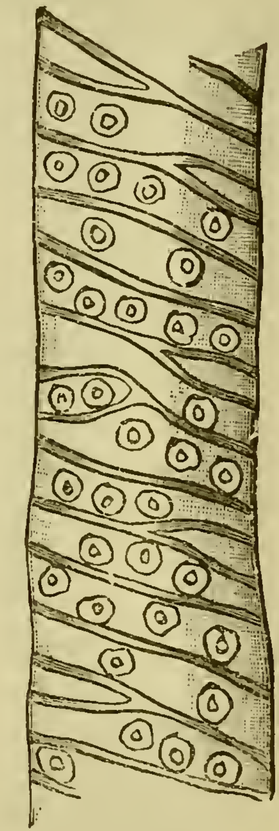

Fig. 35.—Piece of a reticulate and pitted vessel (tracheïd) from the lime, *Tilia grandifolia*. (× 400.)

The increase in thickness of the cell-wall takes a very peculiar form in the epidermal cells of many Urticaceæ and of some other plants. In the interior of specially enlarged cells, stratified and finally club-shaped outgrowths of the wall are formed, in which are deposited small crystals, scarcely or not at all distinguishable as such, of calcium carbonate (Fig. 37). These clustered structures are known as *cystoliths*.

The cell-wall consists of a peculiar substance called *cellulose*, having the chemical composition $C_6H_{10}O_5$. It is found in the pure state only in young cells; in older cells it is often concealed by other bodies which are said to incrust it, or becomes altogether transformed into other substances. Cell-walls are intimately permeated, by means of *incrustation* or *infiltration*, by other substances which are deposited among the particles of cellulose. The cell-walls of many Algæ are converted by incrustation into actual coats of silica, which are often marked with very beautiful tracings, so fine that they are used as test-objects under the microscope; and this is especially the case in the diatoms (Fig. 38). Coats of silica and other inorganic incrusting masses often remain as skeletons after combustion of the cells.

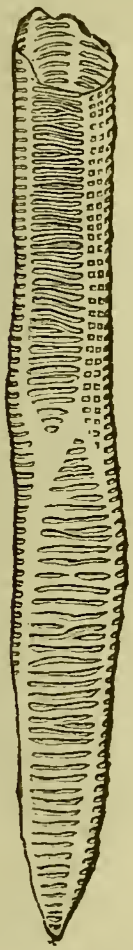

FIG. 36. — Scalariform cell from the underground stem of the brake, *Pteris aquilina*. (× 500.)

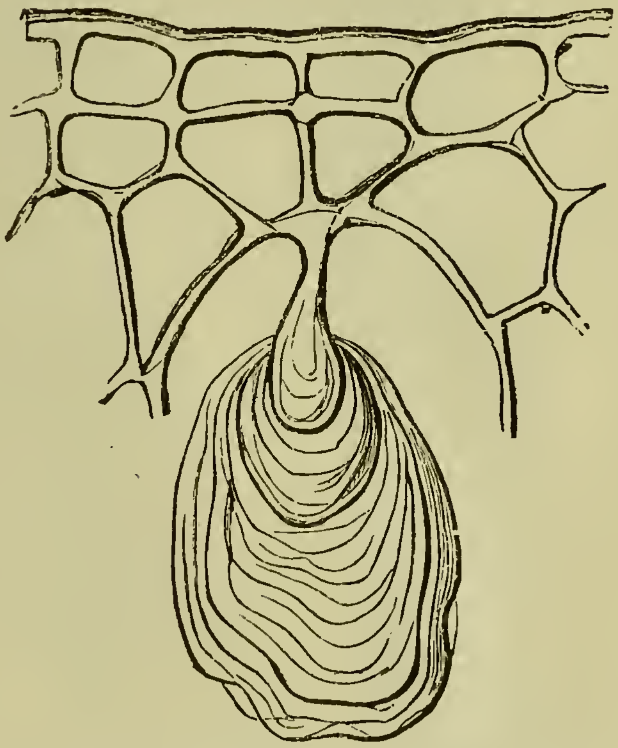

FIG. 37.—Cystoliths from the leaf of *Urostigma elasticum*. (× 370.)

The direct transformation of cellulose into other substances is also a very common phenomenon. The products of tranformation thus formed either impart special properties to the cell-wall, or they are used for the future economy of the plant, or must be looked on as excreta. The most common examples of the first kind are afforded by the *lignifaction* and *suberisation* of cell-walls; *i.e.* the processes by which cellulose is converted into *lignin* or *cork*. The various cases of

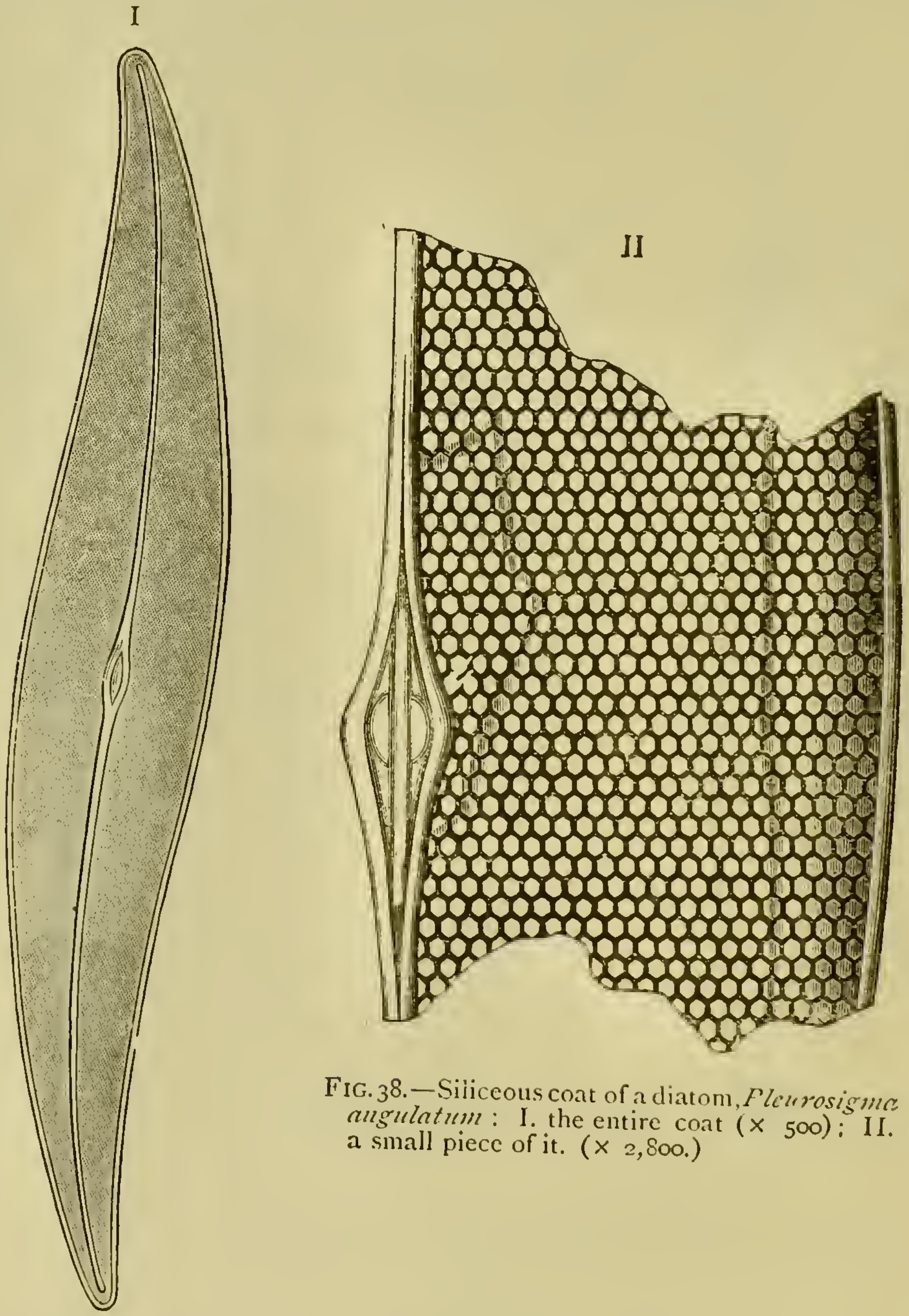

Fig. 38.—Siliceous coat of a diatom, *Pleurosigma angulatum*: I. the entire coat (× 500); II. a small piece of it. (× 2,800.)

the second kind, in which the transformed and absorbed portions of the cell-wall are retained to support the life of the plant, have been comprised under the term *resorption.* To this class belong the disappearance of particular portions of the cell-wall in the coalescence of cells to be here-after described, as well as the resorption in the formation of bordered pits, in which the cell-walls between the canals have become absorbed. As examples of excreta produced from cellulose by transformation, and no longer of service for the life of the plant, at least in the formation and nourishment of cells, we may regard gum-arabic, cherry-gum, gum-tragacanth, and other similar substances. In some cases only particular cells are subject to these transformations; in others all without distinction. Thus, for example, in the stem of the cherry or plum-tree, gum may be produced from any kind of cell. Of a somewhat similar nature to this formation of gum is the *conversion into mucilage* of the epidermal cells of many seeds, as in linseed and quince seeds. In these cases the cell-wall is excessively thickened; but, while otherwise retaining all its special characteristics, the innermost layers swell up to an extraordinary extent in water, so that they burst the outer layers which have not the same property, and emerge as a transparent mucilage (Fig. 39). The secretions of cells, which will be referred to hereafter, must not be confounded with these products of transformation of the cell-wall.

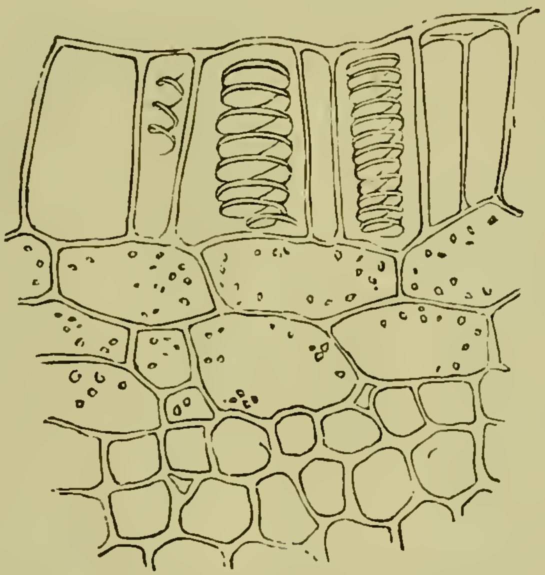

FIG. 39.—Transverse section of a piece of the testa of the seed of *Polemonium cœruleum.* After moistening with water the layers of swollen cells emerge above the outermost cells in the form of a jelly (after Unger).

Besides protoplasm, the nucleus, the watery cell-sap, and the solid substances and gases contained in it in a state of solution, there occur also in the cell various special *cell-contents*. Among the more important substances of this nature are albuminous or proteinaceous substances, chlorophyll, other pigments, starch crystalline formations, aleurone, resin, oils, caoutchouc, sugar, tannic acid, and inulin.

Chlorophyll, the source of the green colour of plants, is always combined with particles of protoplasm of definite form, which in consequence appear of a green colour, and are called *chlorophyll-bodies*. These occur only in those cells which possess a cell-wall, never in naked primordial cells. They are usually lenticular, rarely in the form of bands (as in the Conjugatæ, Fig. 41), stellate figures, or in undefined flakes. Chemists are not yet agreed as to the chemical composition of chlorophyll ; but it is probably composed of two independent colouring substances, a golden yellow and a blue-green ; it is possible also that iron is an essential constituent of it. The access of light is also an indispensable condition for its formation. Plants usually green become bleached or etiolated when grown in the dark ; a very small quantity of light is, however, sufficient to produce chlorophyll in many plants that grow in the shade. The germinating seeds of many Coniferæ and the fronds of ferns afford a striking exception, becoming green even in absolute darkness when the temperature is sufficiently high. The chlorophyll-bodies, which arise from and in the protoplasm, remain subsequently imbedded in it, and are especially found in a motionless layer of the parietal coating ; rarely, as in *Vallisneria spiralis* (Fig. 40), in the currents themselves of the protoplasm. They consist of a colourless protoplasmic fundamental substance, in which the green colouring matter is imbedded. They possess no proper membrane, although the outermost layer is denser, the density decreasing gradually towards the fluid interior. In their interior are often found granules of starch, which have been formed there under the influence of light. The chlorophyll-bodies do not usually increase greatly in size ; when fully formed they multiply by division, each splitting up into two new bodies. [Chlorophyll is readily soluble in alcohol, and possesses a distinct and characteristic spectrum. Much attention has recently been paid to its constitution. Pringsheim regards as its most important ingredient a substance which he calls *hypochlorin*, which can be separated in the form of brown glutinous drops, in which the green colouring matter is dissolved. When first formed, the chlorophyll-bodies are almost destitute of colour. When kept in the dark, the green parts of a plant become gradually bleached or *etiolated*, from the disappearance of the chlorophyll-grains. The variegated colour of leaves in autumn is due to a transformation of the chlorophyll into other analogous substances.]

The parts of plants which are not green, as the petals, have peculiar *pigments* in their cells, sometimes dissolved, sometimes as solid particles. Particles of a red pigment are found, for example, in *Adonis autumnalis*, 0·004 mm. in diameter, of an orange colour in *Zinnia elegans*, yellow in *Kerria japonica*. A violet colour is always, a blue colour usually, due to dissolved pigments. As an example how peculiarly the separate pigments may be distributed in different superimposed layers of cells, the marginal flowers in the capitulum of *Zinnia elegans* are scarlet on the upper, light yellow on the underside, the uppermost layers of cells contain a purple sap with orange granules, all the rest a colourless sap with a smaller number of light yellow granules. Only those cells which

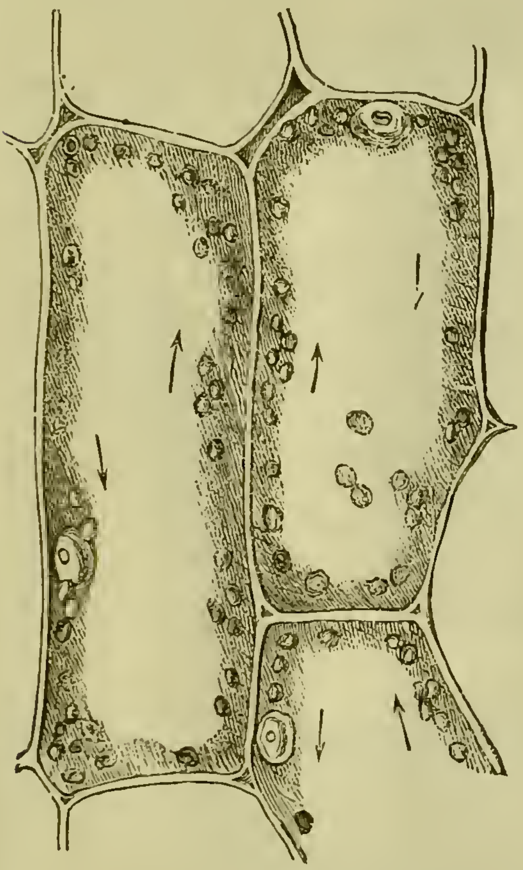

FIG. 40.—Cells from the leaf of *Vallisneria spiralis*. The round bodies are grains of chlorophyll ; the arrows denote the direction of the currents of protoplasm. (× 800.)

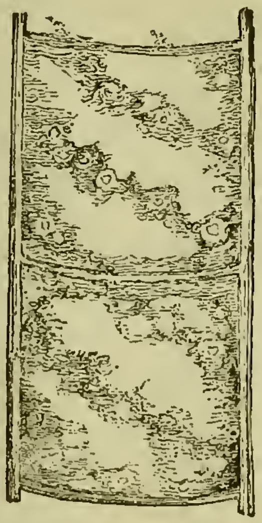

FIG. 41.—Band of chlorophyll in *Spirogyra* (Conjugatæ) : two cells seen from the surface. (× 350.)

are filled with air appear white ; a black appearance depends on a dark shade of a violet or brown colour. The conditions which favour the formation of the bright pigments are not yet known ; the agency of light is not probable, since the bright colouring of flowers appears as soon as the form of the parts of the flower is determined, even though in the dark.

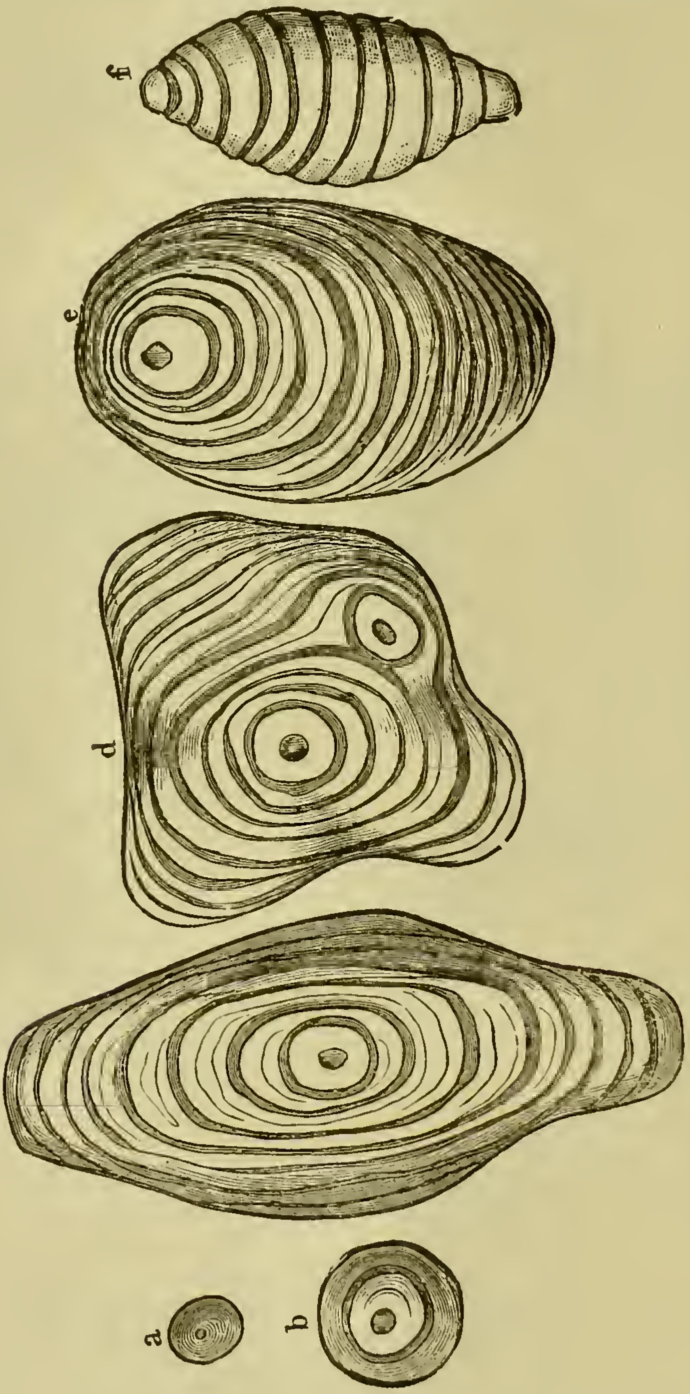

Fig. 42.—Various forms of starch-grain from the potato (greatly magnified).

Still more widely distributed in the vegetable kingdom than chlorophyll is *starch*. With a great external variability in form, grains of starch possess the common characteristic of turning an indigo-blue colour on treating with an aqueous solution of iodine. They have the same chemical composition as cellulose, $C_6H_{10}O_5$; they are insoluble in cold water, but swell up very strongly in boiling water, forming a paste. If starch mixed with saliva is heated for some time to 45° or 55° C., the substance which is coloured blue by iodine is removed. The conclusion which naturally follows, that starch consists of the substance that is coloured blue by iodine, *granulose*, together with a cellulose substance that is not so coloured, called *farinose*, must not, however, be considered as finally determined. The grains of starch are formed originally within the chlorophyll (Fig. 47). On their first origin they appear as infinitesimally small bodies, which are invariably of a spherical form until they have attained a certain size. In the course of their further growth they deviate in a variety of ways from this form (Figs. 42-46) The fully-developed starch-grains of the sorrel and of the tuberous roots of the orchis are spherical ; those of the grains of cereals lenticular ; of the potato ovoid ; grains of the shape of a rod or bone are found in the latex of tropical Euphorbias, &c. (Fig. 46.)

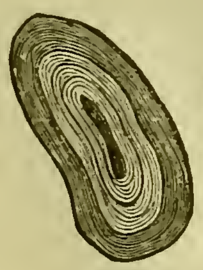

FIG. 43. — Starch-grain from the scarlet-runner. (× 660.)

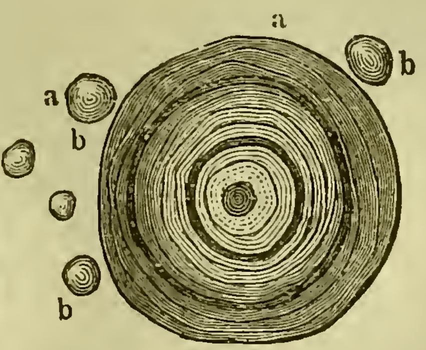

FIG. 44.—*a*, *b*, starch-grains from rye (× 660.)

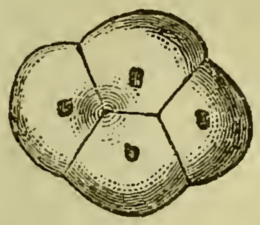

FIG. 45.—Starch-grain from the stem of the sarsaparilla, *Smilax Sarsaparilla*. (× 660.)

Mature starch-grains consist, as a rule, of a number of layers which appear to have been deposited around a central or eccentric nucleus ; but it is impossible to believe that separate layers have been actually so formed in the course of growth ; it is much more probable that they grow by intussusception (see p. 15), and that the stratification is only the consequence of the layers or shells containing a larger or smaller quantity of water, as is shown by perfectly dry grains of starch being unstratified throughout. Those grains which contain two or more nuclei, surrounded by a common system of peripheral layers, are termed semi-compound (Fig. 42 *d*); compound when the divisions which separate the grains have advanced as far as the outer circumference (Fig. 45). In opposition to these truly compound grains those are called pseudo-compound where several are enclosed together in one vesicle, as in a grain of chlorophyll (Fig. 47). Only in a comparatively

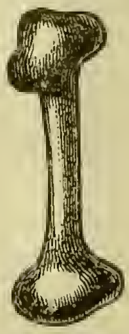

Fig. 46. — Starch-grains from the latex of *Euphorbia splendens*. (× 660.)

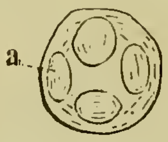

Fig. 47. — Chlorophyll-grain of *Pilea muscosa*, enclosing four starch-grains, *a* (greatly magnified).

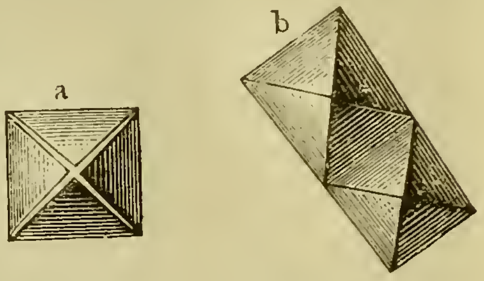

Fig. 48.—Crystals from the leaf of *Begonia heracleifolia*; *a*, a single quadrate octohedron; *b*, twin-crystals of the same form. (× 660.)

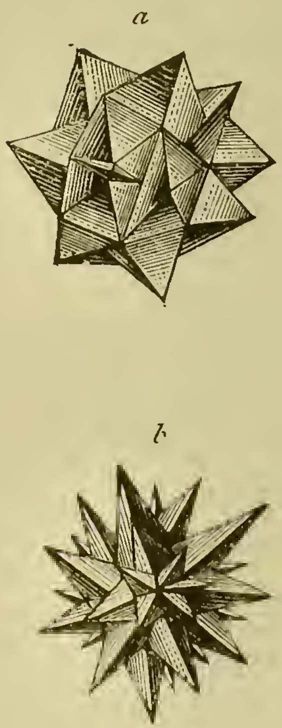

Fig. 49.—Groups of crystals; *a* from the leaf of *Begonia heracleifolia* (quadrate octohedra); *b* from the stem of *Urostigma elasticum*. (× 660.)

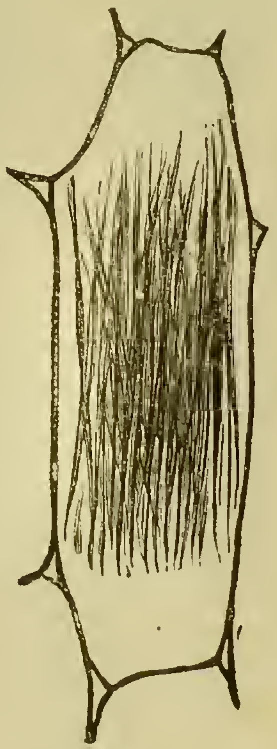

Fig. 50.—Cell from the stem of *Aloë retusa*, with raphides. (× 320.)

small number of groups of plants has no starch been found; but this occurs throughout the class of Fungi. The purpose of the formation of starch is that it may be stored up in the cells as a *reserve food-material*, which becomes dissolved in the subsequent formation of new

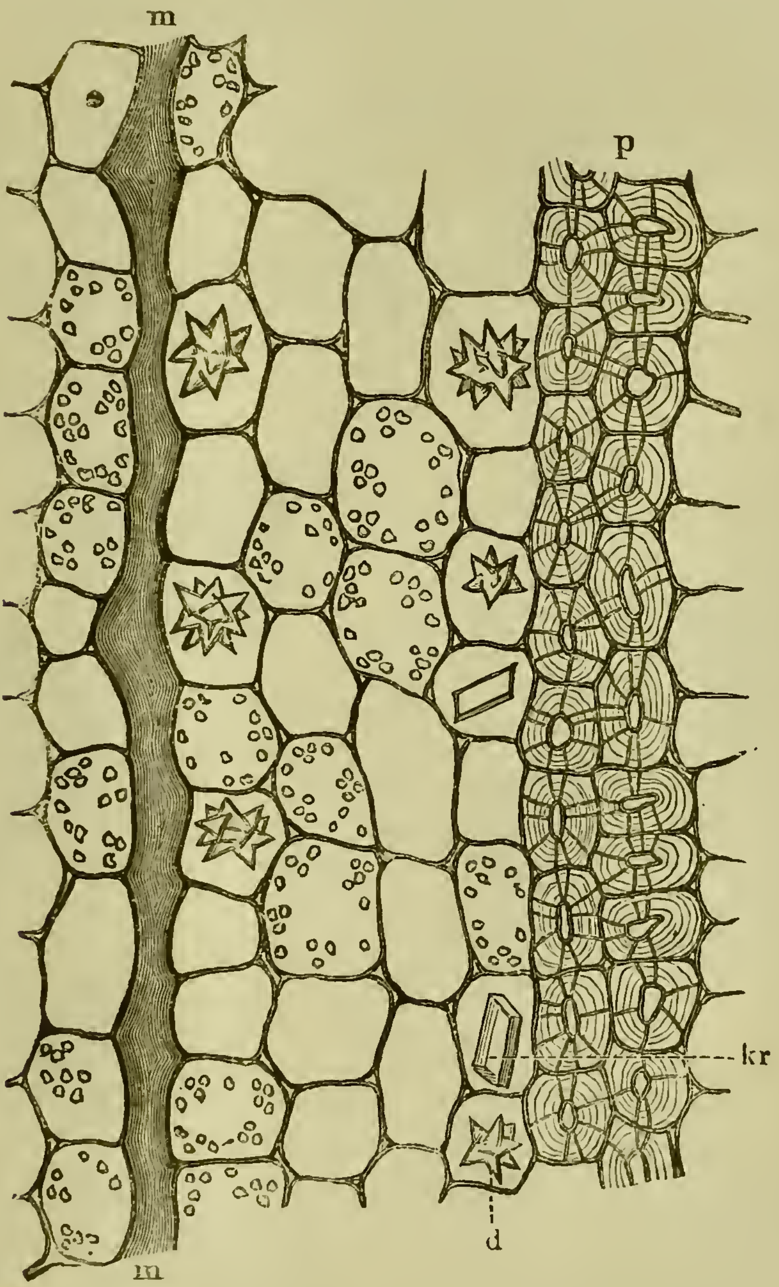

FIG. 51.—Longitudinal section through the inner bark of the stem of *Hoya carnosa*. Together with the thin-walled parenchyma, partly containing chlorophyll with starch-grains, partly crystals *d* and *k r*, are bands of very strongly thickened pitted parenchymatous cells *p*, and laticiferous vessels *m m*. (× 250.)

cells, and can then be used as a formative material. It is, therefore, deposited in especially large quantities in bulbs, tubers, seeds, pollen-grains, and generally in those organs which, when vegetation awakes, form the starting-points of the new formation of large numbers of cells. (See also Chap. V.)

Crystals occur in particular cells in almost all the higher vascular plants, less often also in the less highly organised Cryptogams; and in Conifers are also frequently found imbedded in the cell-wall. They usually consist of calcium oxalate. The crystals, when separate, contain six equivalents of water of crystallisation; their stem-form is a blunt quadrate octahedron (Figs. 48, 49, 51). The bundles of acicular crystals or *raphides* (Fig. 50) have, on the other hand, only two equivalents of water of crystallisation.

The *albuminous* or *proteinaceous* substances contained in the cell are of special importance, since they stand in the closest relationship to protoplasm. Their presence is generally detected with tolerable ease under the microscope, being coloured red by the addition of water and sulphuric acid or mercury subnitrate. They usually appear to be perfectly dissolved in the cell-sap, often as granular masses, more rarely in a crystalline form, as *protein-crystals* or *crystalloids*. They exhibit all the essential properties of protoplasm, and are not true

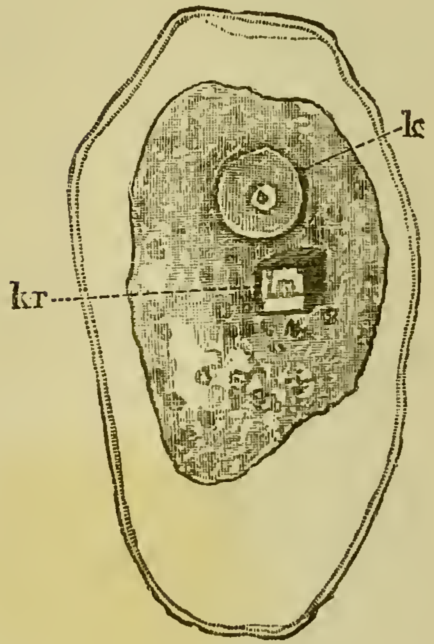

FIG. 52.—Crystalloid *kr*, in a parenchymatous cell of the potato-tuber; *k* nucleus. (× 420.)

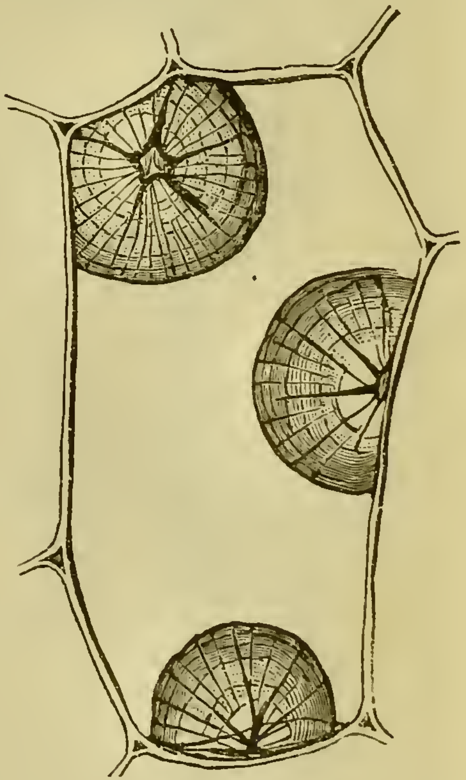

FIG. 53.—Sphere-crystals of inulin in a parenchymatous cell from a tuber of the dahlia preserved in alcohol, after addition of nitric acid. (× 420.)

crystals, differing from these essentially in many respects. The cubic crystalloids of the potato, for example (Fig. 52), are not dissolved by water, but break up in a peculiar manner, so as to appear as if composed of several layers. Crystalloids generally occur in the cells in which reserve food-materials are stored up for future use, especially in oily seeds.

Grains of *aleurone* occur frequently in the endosperm and the cotyledons. In seeds which contain starch this albuminous substance includes only a little oil, and does not form granules, as in the grasses, bean, vetch, sweet chestnut, &c. In oily seeds, on the contrary, such as the Brazil nut, nutmeg, Umbelliferæ, &c., it replaces the starch-grains. Crystals of calcium oxalate, or roundish or clustered granules (*globoids*), a double calcium and magnesium phosphate in which the latter is greatly in excess, are frequently found in the grains of aleurone, imbedded in albuminous substance.

The roots of Compositæ [and of some other plants], and less often the stems, contain a peculiar substance called *inulin*. In the living cell it occurs only in solution, and is only precipitated on evaporation or on the addition of alcohol or of some other substance that has a strong attraction for water. If the process is successfully and rapidly performed, the inulin has the form of fine granules which have often a frothy appearance ; but if the process goes on for a considerable time, it forms beautiful spherical bodies, called *sphere-crystals* (Fig. 53). In its composition inulin is analogous to starch.

Besides these substances and those already mentioned, others often occur dissolved in the cell-sap, the presence of which is proved by chemical tests, but which cannot be detected in the cell itself even by the microscope. To this class belong especially the *alkaloids*, strychnine, brucine, chinine, cinchonine, &c.

[*Continuity of Protoplasm.* The cell, while in a living condition, has till lately been regarded as being always a perfectly closed vesicle with unperforated cell-walls. Recent researches have, however, shown that in some cases, especially in endosperm-cells, in the motile organs of such leaves as those of *Mimosa*, and in the fronds of many Florideæ, very delicate threads of protoplasm pass through the cell-wall, and maintain a connection between the protoplasmic contents of adjoining cells. The sieve-pores of sieve-tubes are also penetrated by similar threads of protoplasm.]

By the term *Cell-formation* is understood the mode of origin and multiplication of cells. Four main types of cell-formation may be distinguished :—

1. The *Renewal* or *Rejuvenescence* of a cell, *i.e.* the formation of a single new cell from the entire protoplasm of a cell already in existence. This occurs in the formation of a zoospore out of the entire contents of a vegetative cell, especially among the Algæ (see Classification of Algæ, Chap. VI.)

2. *Conjugation*, or the coalescence of two or more protoplasmic bodies in the formation of a cell. This begins with the lateral approach of two neighbouring cells, and the appearance of an opening at the point of contact, concluding with the complete union of the contents of the two cells for the purpose of reproduction. In its typical form it is limited to a few Algæ and Fungi. (Fig. 54.)

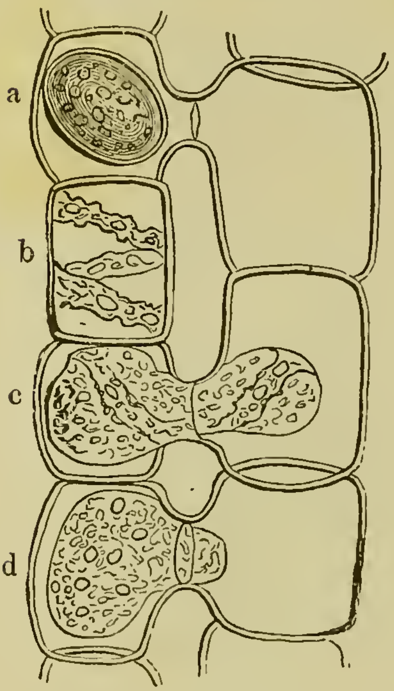

FIG. 54.—Conjugation and formation of zygosperm in *Spirogyra quinina*: *a* a mature zygosperm; *b* a cell not yet conjugated; *c*, *d* successive stages of conjugation. (× 320.)

3. *Cell-division*, or the division of the protoplasmic contents of the original *mother-cell* into portions from which are formed the new *daughter-cells*. When the original cell possesses a nucleus, this process is preceded by the division of the nucleus. This is by far the most common form of the multiplication of cells, since upon it depends all normal vegetable growth.

In the course of the division of the cell, the nucleus undergoes great changes. It becomes coarsely granular, and appears striated longitudinally in a direction at right angles to that in which the cell is dividing; the separate threads become thicker in the middle, and form the *nuclear*

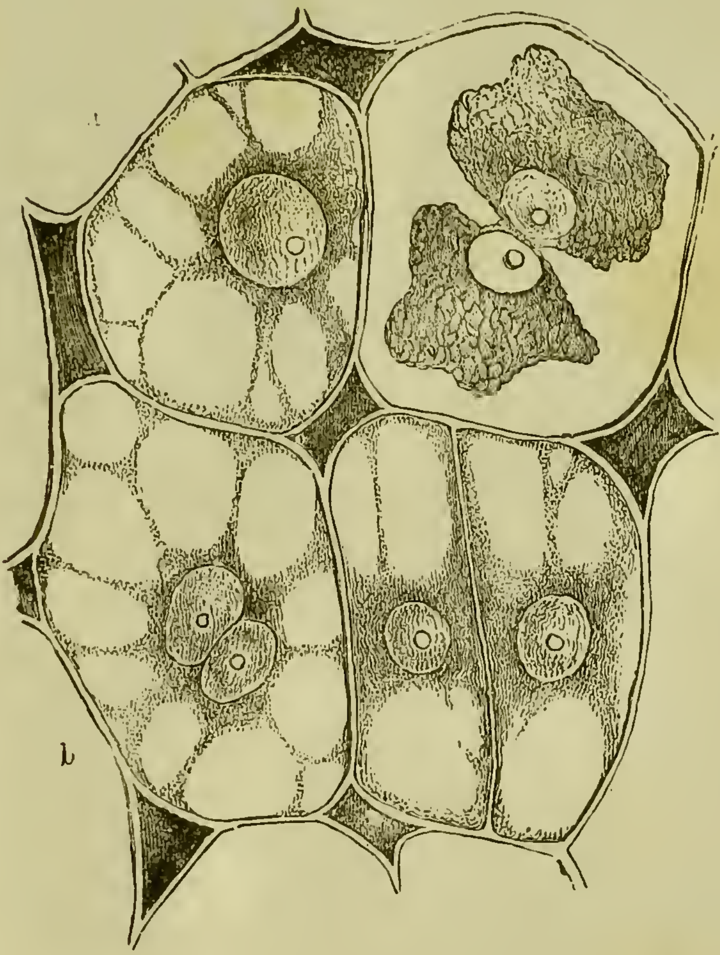

FIG. 55 I.—Cell-division in the endosperm of the scarlet-runner seed. The cells which originated by free cell-formation have closed up, and now multiply by division; *a* mother-cell in its unchanged state; *b* commencement, *c* completion of division into daughter-cells; *d* a similar cell to *b*, the contents of which have been contracted by the addition of water. (× 670.)

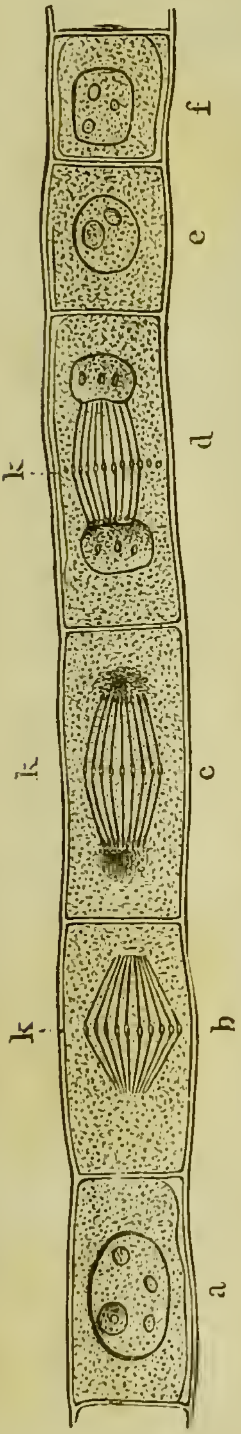

FIG. 54 A.—Cell-division in the hair of a filament of *Tradescantia* (after Strasburger). In *b* the nucleus has already assumed the striated condition; in *c* the division of the nucleus is completed; in *d* the nuclear plate *k* is already formed, and the young nuclei further developed: *e*, *f* young cells in which division has just taken place; *a* mature cell.

plate (see Fig. 54 A), the two new nuclei being formed at its ends. After the division of the nucleus, the first stage of cell-division, the formation of the new cell-wall takes place, which may be either gradual or simultaneous. In the latter case (Fig. 55 I) the formation of the nuclear plate is followed by that of a plate of cellulose, the first rudiment of the new cell-wall. The threads of the original nucleus which still remain then disappear, and the daughter-cells are now fully formed. When the cell-wall is formed gradually, it first makes its appearance as a narrow ring on the inner surface of the wall of the mother-cell, this ring gradually increasing in breadth until it becomes a plate which divides the entire cavity of the mother-cell into two chambers. This mode occurs in the formation of the cell-wall of many filamentous Algæ (Fig. 56) ; the simultaneous formation is the ordinary mode of increase of vegetative organs.

A special form of cell-division is that known as *Gemmation*, which occurs especially in *Saccharomyces* (see Fig. 381, p. 249). A vesicular protuberance here makes its appearance on the mother-cell, into which a portion of the protoplasm enters ; this protuberance is ultimately cut off by a wall of cellulose, and the two cells then separate from one another. The daughter-cell may put out similar buds before its separation from the mother-cell ; and in this way colonies of buds are formed.

4. In *Free Cell-formation* the masses of protoplasm of the mother-cell collect around the nuclei previously produced, and thus form themselves into new cells which remain enclosed within the mother-cell, the life of which still continues for a time. In most cases they have already formed a cell-wall of cellulose while still enclosed within the mother-cell, as in the case of pollen-grains and the embryo-sac of Phanerogams (Fig. 55 II.) ; less often not till after their escape, as occurs in zoospores. [Free cell-formation

occurs only in the formation of organs connected directly or indirectly with reproduction, not with ordinary vegetative growth.]

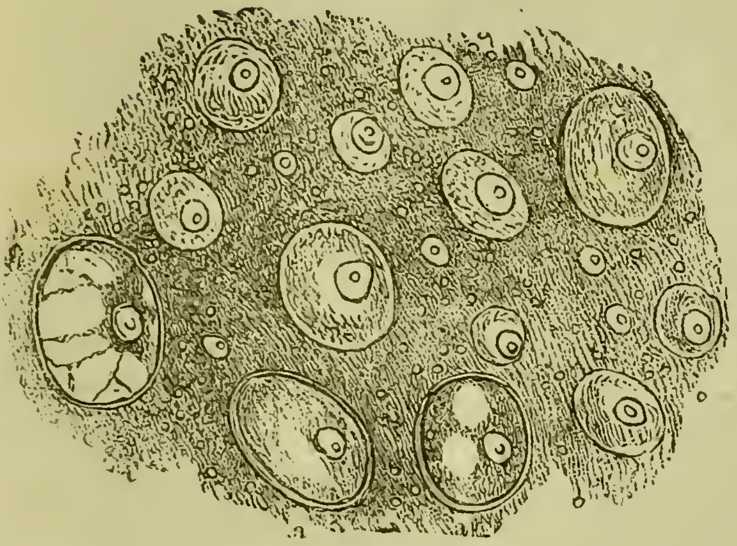

FIG. 55 II.—Free cell-formation in the embryo-sac of the scarlet-runner; *a a* cells already perfect. (× 670.)

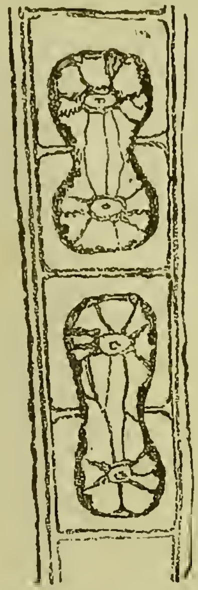

FIG. 56.—Two cells of *Spirogyra* in the act of division, after contraction of the cell-contents by the addition of a solution of sugar, the portions of the cell-wall already formed being thus made visible. In each half of the cell is a secondary nucleus, from which bands of protoplasm proceed to the margin. (Strongly magnified.)

CHAPTER II.

THE CELL AS A MEMBER OF A GROUP OF SIMILAR CELLS.

ONLY a comparatively small number of plants consist, during the whole period of their existence, of a single cell; in the greater number the cells are united into groups. The production of these groups of cells is caused by two circumstances:—In the first place, the cell-walls of young contiguous cells, where they are in contact with one another, amalgamate into a homogeneous mass; and secondly, cells originally distinct coalesce with one another when the portions of the walls that are in contact are of nearly the same nature. This union of adjacent cells is so intimate that it can be artificially destroyed only by chemical reagents which dissolve the outermost layers of the cell-walls themselves. It nevertheless happens very frequently that, in consequence of the unequal growth of adjacent cells, the cell-walls which have already coalesced again partially or entirely separate from one another, so that a cavity or *intercellular space* is formed between these cells (Figs. 60, 63) The form and arrangement of these small intercellular spaces differ greatly in different plants, and in different parts of the same plant. They occur, for example, between the spherical cells of certain groups, where they form together a system of *intercellular passages*, which often increase into capacious air-cavities, air-canals, or large open spaces. The causes which co-operate in the formation of these intercellular spaces may be very various ; in addition to the separation of cells previously united, a dismemberment and subsequent drying up of dead cells may be especially mentioned.

There is no special substance uniting and uniformly cementing together the individual cells ; but if groups of thick-walled cells are examined, it is generally found that the contiguous cells are connected together by a uniform median layer apparently common to the two cells. It was the figuring of this structure (Fig. 57) which originated the idea of a peculiar 'intercellular substance' not belonging to the cells ; but a more exact investigation, especially of the development of the groups of cells, shows that even in these cases there is no independent median layer, but rather a region where a coalescence has taken place of contiguous cell-walls which may have undergone in the course of their growth some important change in their chemical nature.

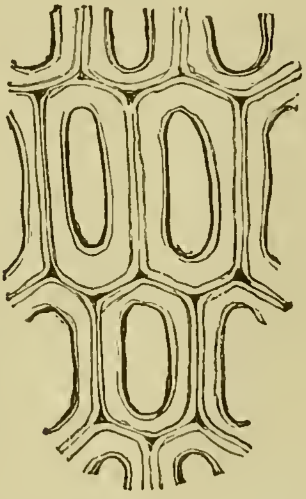

FIG. 57.—The so-called ' intercellular substance,' as delicate lines which unite in the angles between the cells of the wood of a Conifer. (× 400.)

Certain differences exist in the groups of similar cells, according to which they are distinguished as families of colonies, tissues, and fusions of cells.

A *cell-family* originates from a single mother-cell; and each of the daughter-cells preserves its own individuality, which can even proceed as far as separation from the family. In *Pediastrum rotula*, for example (Fig. 58), the green contents of each mother-cell break up into several spherical daughter-cells; the innermost membrane of each separate mother-cell then protrudes through a fissure and rapidly enlarges, in order to make room, in the cells formed in it, for a creeping motion which lasts for some time. As soon as this motion ceases, the sister-cells place themselves together so as to form a plate, and produce in their development a new colony. Cell-families occur only in the lowest classes of plants, the Algæ and Fungi (Fig. 59).

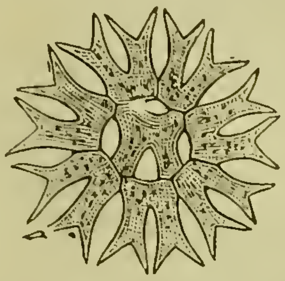
Fig. 58.—A family of *Pediastrum rotu'a* (an Alga) consisting of eight cells. (× 250.)

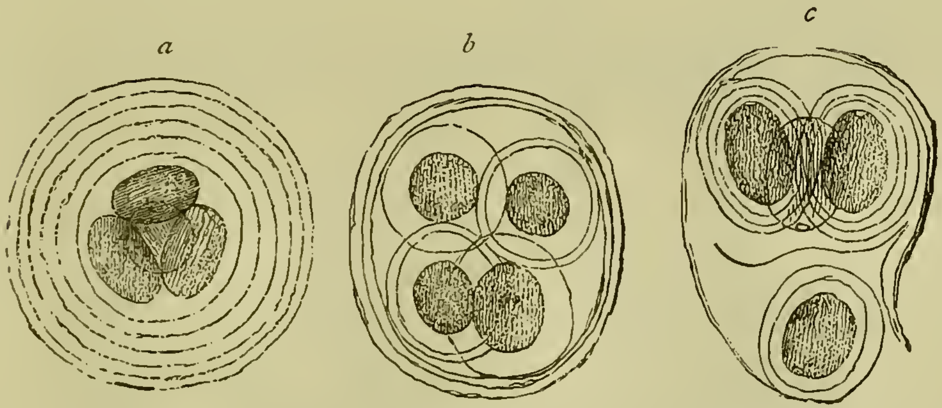

Fig. 59.—*Pleurococcus superbus*: *a* a family of four cells; the cells themselves are naked, but the whole family is enclosed in a common cell-wall consisting of six layers; *b* each cell has developed a separate cell-wall; *c* the original cell-walls have burst, and the separate cells have become free; they continue for some time in motion, then come to rest, and develope new families. (After Cienkowski, × 320.)

The union of cells into *tissues* and *cell-fusions* is permanent, and is combined with a limitation in various ways of the functions of the separate cells. In the former the cells unite only into a group, the elements (separate cells) of which can still be easily recognised, and still possess a certain individuality; in the latter, on the contrary, the separate cells coalesce into a single individual, the elements of which are often completely indistinguishable as such. Both are of much greater importance in the vegetable world than cell-families, since their occurrence is incomparably more frequent.

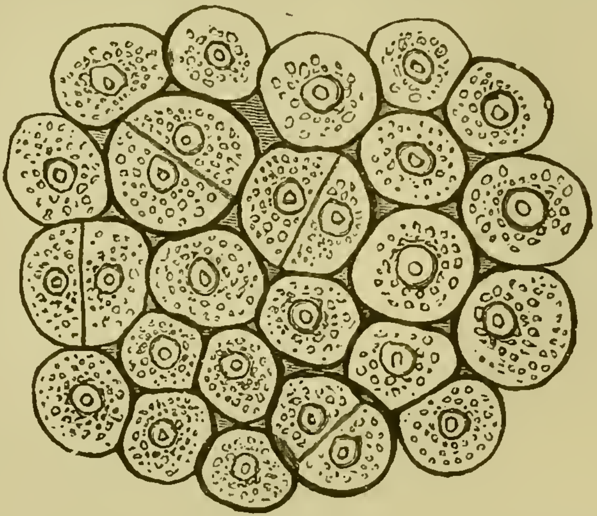

FIG. 60.—Transverse section through the growing point or primary parenchyma of the fig, *Ficus carica*; the cells are still roundish and in the act of dividing. (× 1200.)

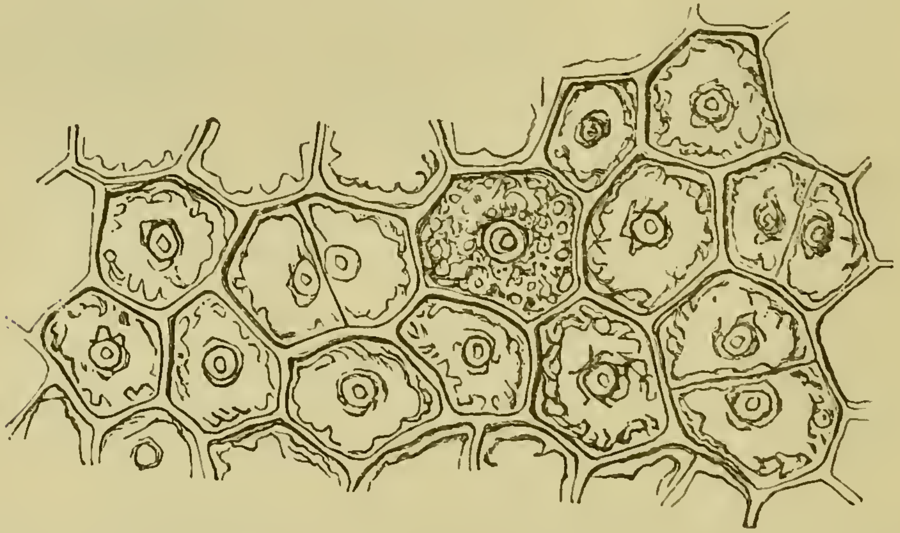

FIG. 61.—Parenchymatous tissue; transverse section through a deeply buried part of the pith of the apex of the plumule of the horse-chestnut; the cells have become crowded and hence polygonal; only a few have as yet divided. (× 800.)

If the cells which constitute a tissue are pointed at their ends, much longer than broad, and dovetailing into one another, the tissue is called *prosenchyma.* If the cells, on the other hand, are arranged in rows, are bounded by flat or curved walls, and not much longer than broad, it is called *parenchyma.* The two kinds of tissue frequently pass over into one another, and may be more or less regular according to the mode in which the cells have been developed (Figs. 60-63). To special forms the terms *collenchyma* and '*tela contexta*' have been applied. The former usually consists of cells which have become more strongly thickened at the corners than at the sides; the thickening-masses are also capable of swelling, so that when they lie in water they appear glossy and swollen, and assume a gelatinous or mucilaginous character (Fig. 64). 'Tela contexta' is a tissue in which the simple or branched elongated thread-like cells are not regularly united to one another, as is the case in the kinds of tissues previously described. The separate cells are in this case arranged in threads which do not run parallel to one another, but cross irregularly, forming a tissue the separate cells of which are not unfrequently grown or cemented together in an intimate manner and in a variety of ways. This occurs in Fungi, Lichens, and some Algæ (Fig. 65, p. 42). Some-

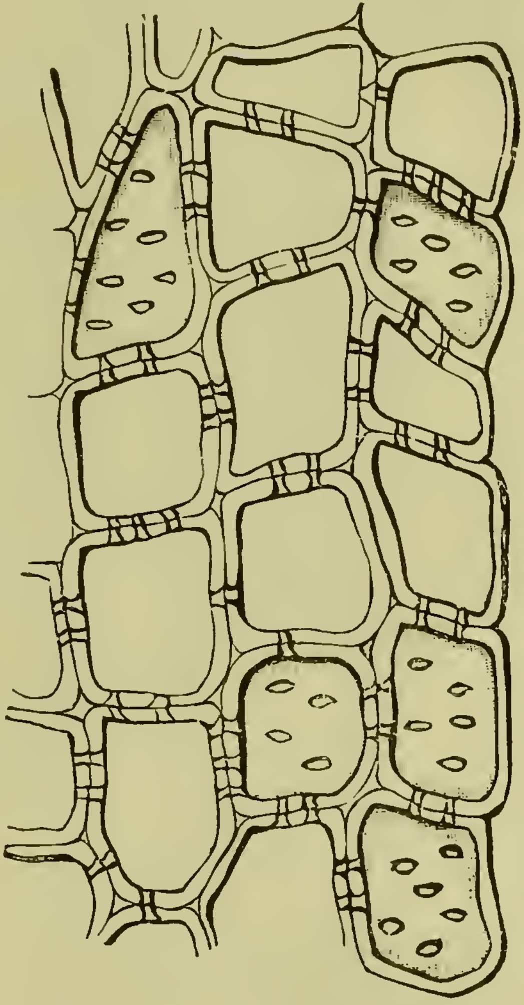

FIG. 62.—Moderately thickened pitted parenchyma from the pith of the beech. (× 320.)

times, especially in the pileus of certain Fungi, particular cell-layers of a 'tela contexta' form an apparently regular parenchyma, in which however the whole course of development shows that we have here distinct but contiguous filaments of cells (*i.e.* filaments of distinct cells arranged in rows); and a tissue of this kind has therefore been called a *pseudo-parenchyma.* [A tissue composed entirely of sclerenchymatous cells (Fig. 25, p. 17) is known as *sclerenchyma*, and is one of the hardest tissues known in the vegetable kingdom. Good examples occur in the 'stone' of stone-fruit, the shell of nuts, &c.]

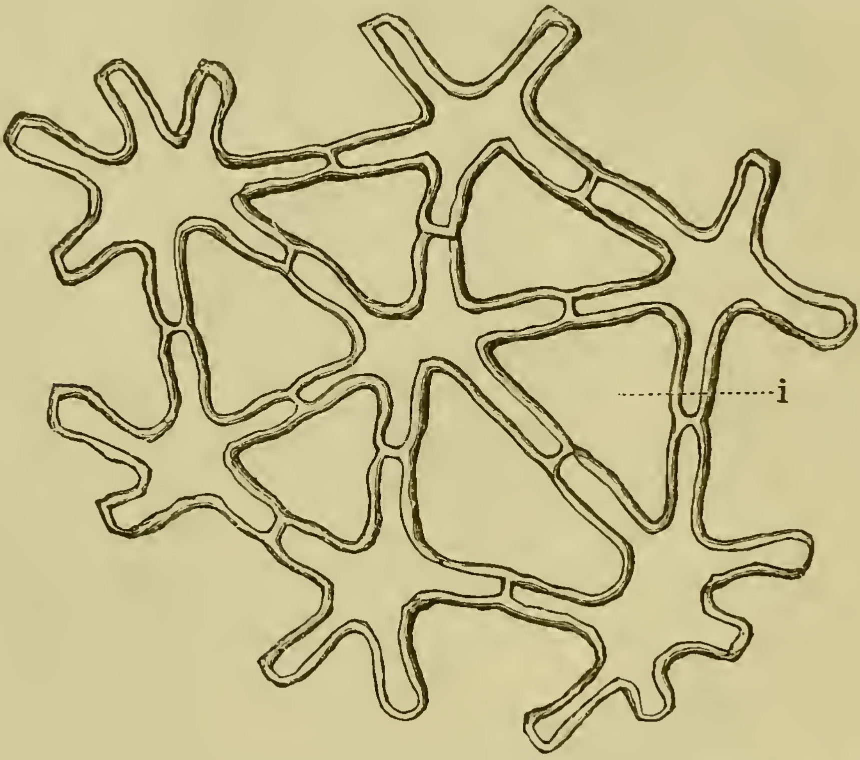

FIG. 63.—Stellate parenchyma from the pith of the rush, *Juncus conglomeratus* ; *i* intercellular space. (× 250.)

With respect to the production of new cells, even superficial observation shows that, at least in the higher plants, as for example in trees, it does not proceed everywhere uniformly, but is confined to particular spots. To spots of this nature the terms *growing point*, *cone of growth*, and growing or formative layer, have been applied, according to their degree of development. Instances of growing points occur in the apices of buds; of formative layers between the wood and the bark of [exogenous] trees. Both owe their special character to the formation of new cells or organs by means of a special tissue to which the names

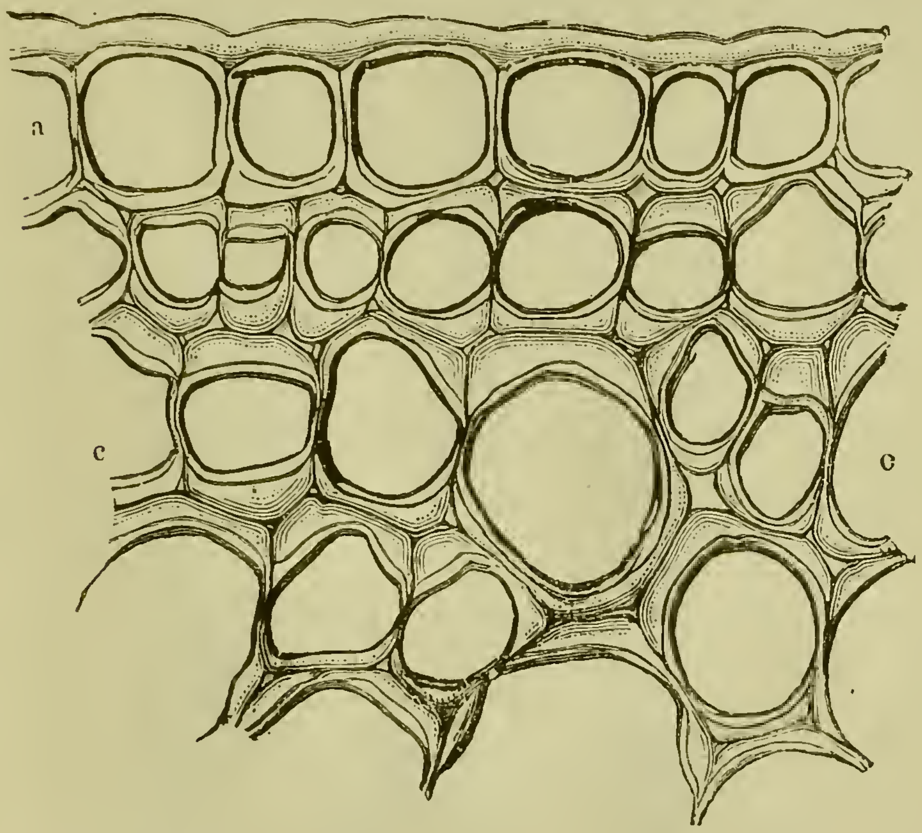

FIG. 64.—Transverse section through the collenchyma of the sowthistle, *Sonchus asper*: *a* epidermis: *c* collenchymatous cells. (× 670.)

formative or *generating tissue* and *meristem* have been given. In contrast to this, a tissue in which the cells are not as a rule capable of dividing, is called a *permanent tissue*, and the separate cells which no longer serve for the formation of new cells, permanent cells.

The generating tissue of the growing point of flowering plants is parenchymatous, and is called primary parenchyma or *primary meristem*, because every kind of cell and every part of the plant may or actually does develope, directly or indirectly, from it. Independently of growth by the actual increase in size of the individual cells, the apical growth of plants depends mainly on the constant fresh formation of this tissue.

The increase of thickness in plants, on the contrary,

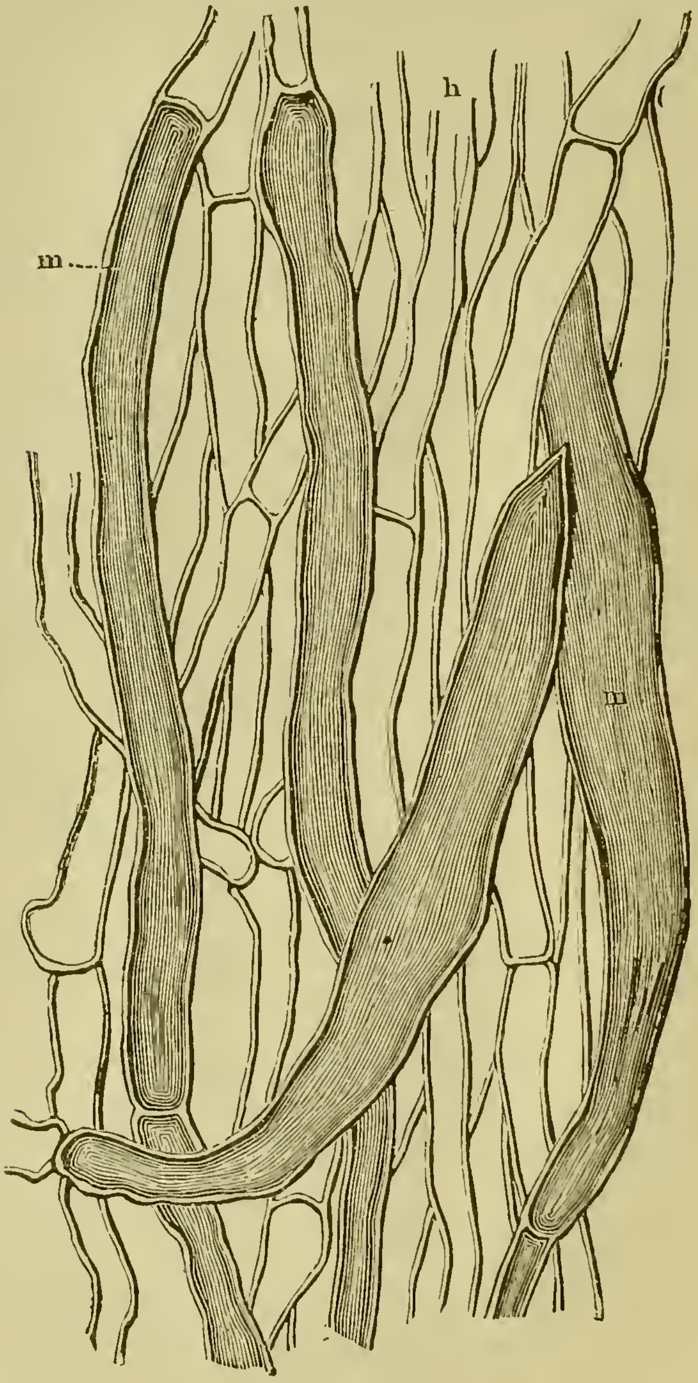

FIG. 65—'Tela contexta' from the medullary layer of the pileus of a Fungus, *Amanita muscaria*; *h* ordinary cells; *m* laticiferous cells. (× 360.)

occurs especially in those parts where there are permanent structures which increase in diameter during the whole period of their existence, chiefly or even exclusively from the formation of a special generating tissue, the *cambium.* The cambium is usually a prosenchymatous tissue, not found in the growing point, but distributed elsewhere in very various parts of the plant. To it is due the final development of the fibrovascular bundles, which however originate in its forerunner, the *procambium.* The cambium forms, according to circumstances, a central cambium-cylinder, or isolated dispersed cambium-bundles, or a cambium-ring. A thickening-ring of this character occurs, for example, in the layer formed between the wood and the bark of those trees which are characterised by the formation of annual rings. In the most lowly organised plants, the Fungi, Lichens, and Algæ, both kinds of generating tissue are wanting, and every one of the cells has an equal capacity for originating new vegetative cells, *i.e.* such as serve only for growth and not for reproduction. Although the production of new cells is the special province of the specific generating tissues now described, this does not imply that the elements of other tissues are entirely destitute of this power; on the contrary, it is strikingly manifested in the annual and especially in succulent parts of plants.

In direct contrast to the generating tissues are the *healing-tissues*, suberous tissues, or cork-tissues. The former are of service to the plant by their long-continued and vigorous growth and the formation of new cells; while the latter, dying quickly, lose their cell-sap; their cell-walls become converted into cork, and thus form a mantle or envelope which protects the subjacent cells from injurious influences of all kinds. Two kinds of this tissue are distinguished—true cork or suber, and periderm; the two are not, however, sharply separated, but pass into one another in a variety of ways.

True *cork* is a very elastic tissue consisting of thin-walled, usually nearly cubical, cells (Fig. 66). It does not peel off, but often contains long clefts, as is commonly seen in the bark of the maple.

Periderm consists of tabular cells with thicker walls, which, when looked at vertically, have a regular polygonal or stellate appearance. It has in general more vital power, and is firmer, less elastic, and more leathery than true cork. When it is several layers in thickness, thick and thin-walled layers often alternate (Fig. 67), causing frequently a peeling off, as in the birch and cherry; in the beech and silver fir, on the contrary, the periderm does not peel off.

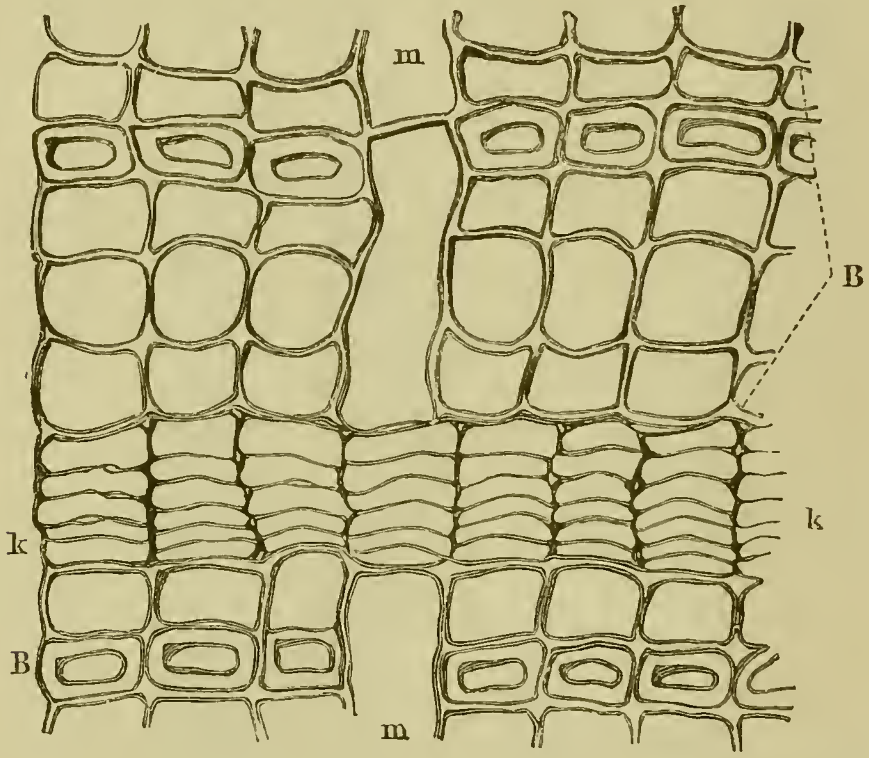

FIG. 66.—Transverse section through the bark of the juniper; B B bast-cells; *m m* medullary rays; *k* layer of cork formed of thin-walled cells parallel to the circumference of the stem. (× 370.)

Cork is the true healing-tissue of plants, and as such is of great importance. In the fresh surfaces of wounds, the uppermost layers of cells as a rule dry up, while in the tissue beneath them, still full of sap, new cells are formed which are the origin of the cork. A very good example of the importance of this production of cork is afforded by the cochineal-cactus. This plant is multiplied by cuttings, which would decay at once if they were set in the ground with the surfaces of the wound fresh. The shoots which are intended as cuttings are therefore first laid for about four weeks in a dry place exposed to the sun, in

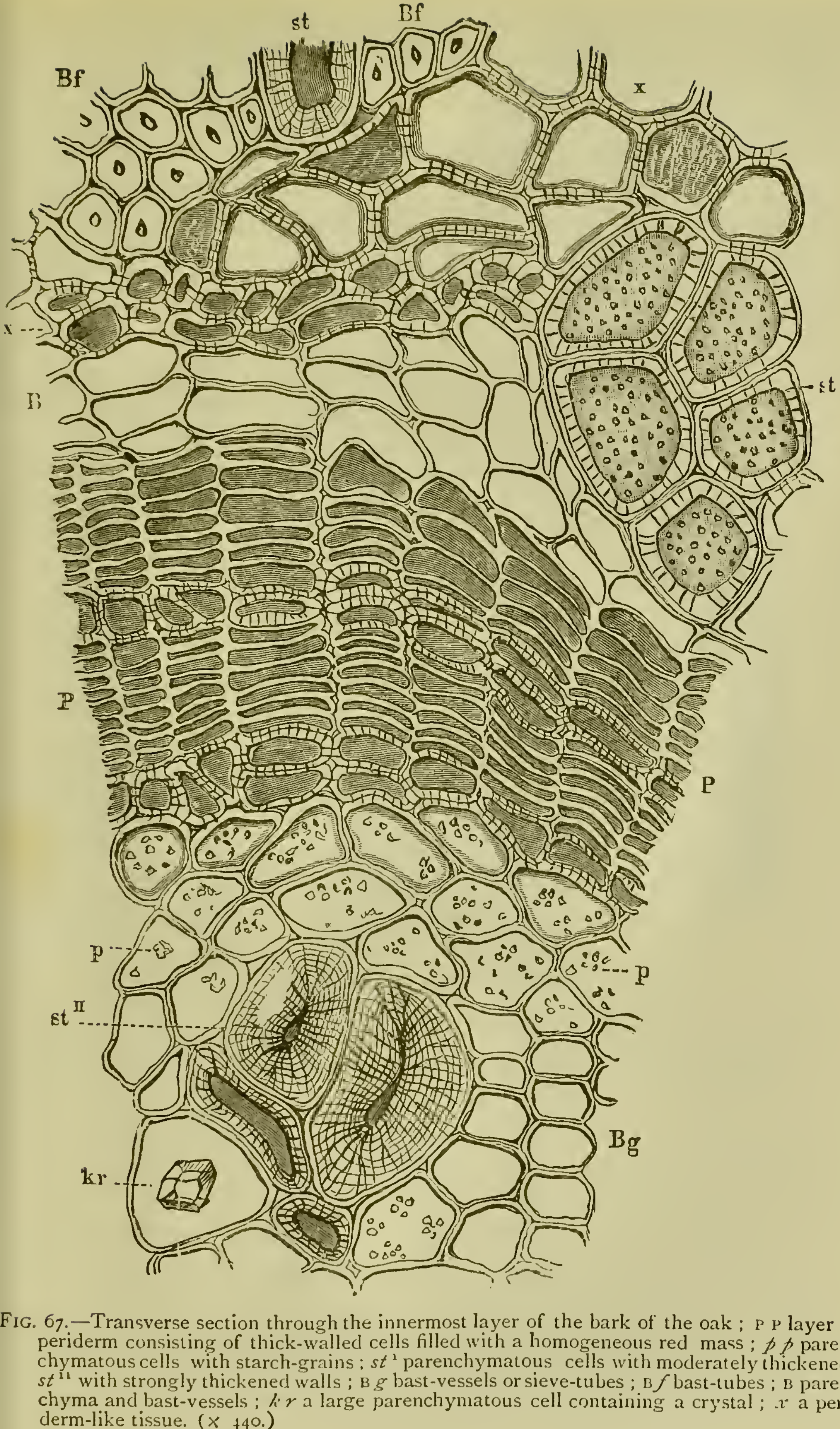

Fig. 67.—Transverse section through the innermost layer of the bark of the oak; P P layer of periderm consisting of thick-walled cells filled with a homogeneous red mass; *p p* parenchymatous cells with starch-grains; st^{I} parenchymatous cells with moderately thickened, st^{II} with strongly thickened walls; B *g* bast-vessels or sieve-tubes; B *f* bast-tubes; B parenchyma and bast-vessels; *k r* a large parenchymatous cell containing a crystal; *x* a periderm-like tissue. (× 440.)

order that a cork-tissue may be formed, which closes the wound and prevents the decay of the cutting.

Larger wounds, as, for instance, when branches are cut off, are often closed by the formation of elevated cushion-shaped masses of cells, not consisting entirely of cork-tissue, which are fresh formed over the whole surface of the wound. Such a tissue is called an overgrowth, and is seen especially in the beech, silver fir, and lime (Fig. 68). Of a similar nature is the *callus*, to which we shall recur when speaking of reproduction by means of cuttings.

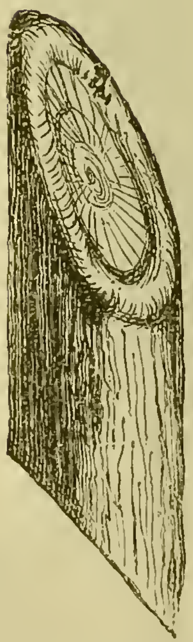

FIG. 68.—Overgrowth on a branch cut through obliquely (natural size.)

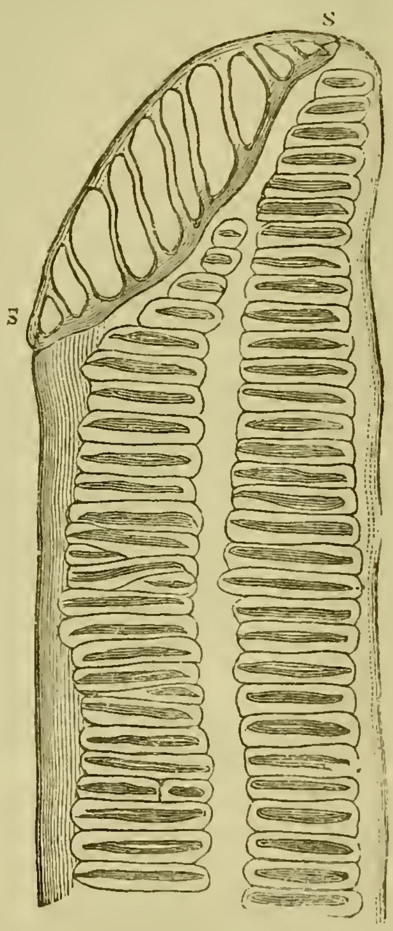

FIG. 69.—Portion of a scalariform vessel from the brake, *Pteris aquilina* ; *s s* the transverse division-wall broken through in a reticulate manner. (× 370.)

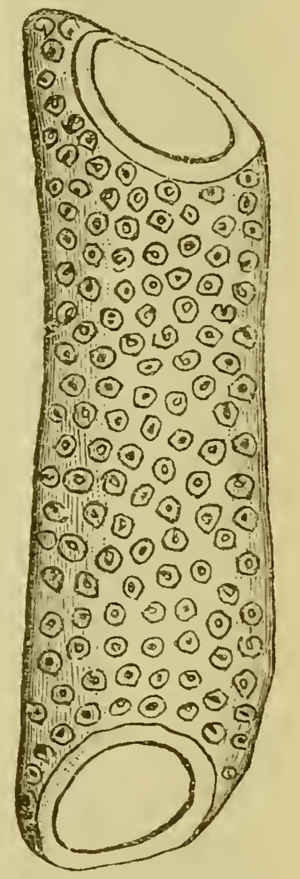

FIG. 70.—Pitted vascular cell from the stem of a grass, *Phragmites communis*, with numerous small bordered pits. (× 400.)

Smaller developments of cork at particular points of the surface, which assume characteristic forms according to the species, are termed *lenticels*. They appear in young branches before the formation of periderm, and occur in the birch, beech, elder, &c.

The special characteristic of *cell-fusions* consists in the cells of which they are composed uniting completely by coalescence into a uniform whole of a higher type. Unions of this kind are usually accompanied by the transformation and absorption of at least a portion of the surfaces of contact. Fusions of a less complete kind have already been described in the coalescence of the contiguous cells of 'tela contexta;' unions of a more perfect description occur in conjugation and the formation of vessels.

The process of *conjugation*, to which reference has already been made, begins with the lateral coalescence of two contiguous cells, and the formation of an opening at the point of contact; finally the contents of the two cells coalesce in the production of a zygosperm (Fig. 54, p. 32). This process has hitherto been observed only among Fungi and Algæ, and especially in the family of Conjugatæ belonging to the latter.

Vessels arise from the coalescence of several cells, which are then termed *vascular cells*; the division-walls partially disappearing while the union continues at the margin. Vessels are divided, according to their form and contents, into vessels in the true sense of the word, bast-tubes or bast-fibres, sieve-tubes or bast-vessels, utricular vessels, and laticiferous vessels.

If a number of spiral cells are imagined placed one over another and coalescing from the more or less complete absorption of the partition-walls, a *spiral vessel* is produced. Vessels are formed in a precisely similar manner, from several of the kinds of cells previously described; and we thus get *annular vessels*, *reticulate vessels* (Fig. 35, p. 20), *scalariform vessels* (Fig. 69), and *pitted* or *dotted vessels* (Fig. 70). [An elongated dotted or pitted vessel is known as a *duct* (Fig. 35).]

The individual vascular cells sometimes stand vertically one over another, and coalesce by their horizontal faces; sometimes they are in contact laterally, and with faces that stand obliquely. The partition-walls do not always entirely disappear; but often, especially when they stand obliquely, portions remain which are more strongly thickened and of a reticulate or scalariform character (Fig. 69, *s s*). True vessels usually become lignified, but are never branched, or at all events extremely rarely. In the mature state they contain nothing but air ; but occasionally in the spring a portion of the sap sucked up by the roots is pressed into these air-containing vessels, a process on which depends, for example, the 'weeping' of wounded grape-vines. In many Vascular Cryptogams, Gymnosperms, and Monocotyledons, as well as in a few Dicotyledons, rows of vascular cells are found in places where, from the analogy of other plants, one would expect to find vessels, the partition-walls not having become absorbed. Such structures compose what is called a *conducting tissue* ; and the separate cells are not called vascular but *conducting cells.*

Bast-tubes or *bast-fibres* are long pointed vessels—not cells, because their elements have completely coalesced—usually thick-walled, rarely branched. They are not often in direct communication with one another, and then always only by lateral branches. They are commonly united into bundles, and as such form an essential part of many fibro-vascular bundles (see Chap. VI.).

While in vessels the separate vascular cells of which they are composed can still be made out with tolerable ease, this is by no means the case in bast-tubes ; on which account opinion was long divided among botanists, whether bast-tubes—the development of which is generally extremely difficult to observe—are formed by the coalescence of cells, or by a single cell increasing from 20 to 50 times its original length. The simple consideration, however, that if the growth of bast-tubes were of the latter nature, it must be accompanied by an increase in thickness of the entire bundle of which it formed a part, which is not actually the case, shows that they can arise only by the coalescence of cells.

A close relationship subsists between sieve-tubes, utricular vessels, and laticiferous vessels, partly on account of their form, partly of their contents ; all appearing to have for their function the storing up of nutrient fluids, and the conducting of them to the parts of the plant where they are required.

Sieve-tubes or *bast-vessels* result from the coalescence of cells standing one over another, the partition-walls of which, or *sieve-discs,* have become perforated in the manner of a sieve ;

and some have also sieve-like perforations through their side-walls (Figs. 71–74). Of similar construction are *lat-*

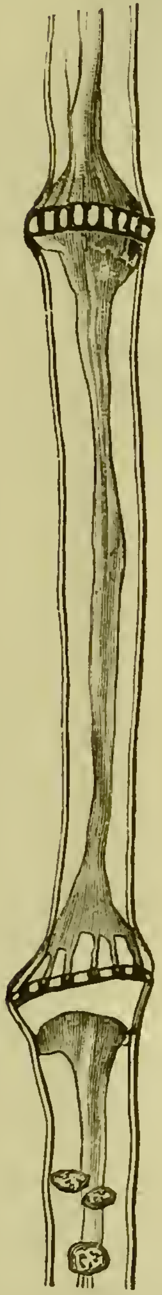

Fig. 71.—Sieve-tube from the white bryony, *Bryonia dioica*, the horizontal partition-walls with peculiar thickenings. (× 250.)

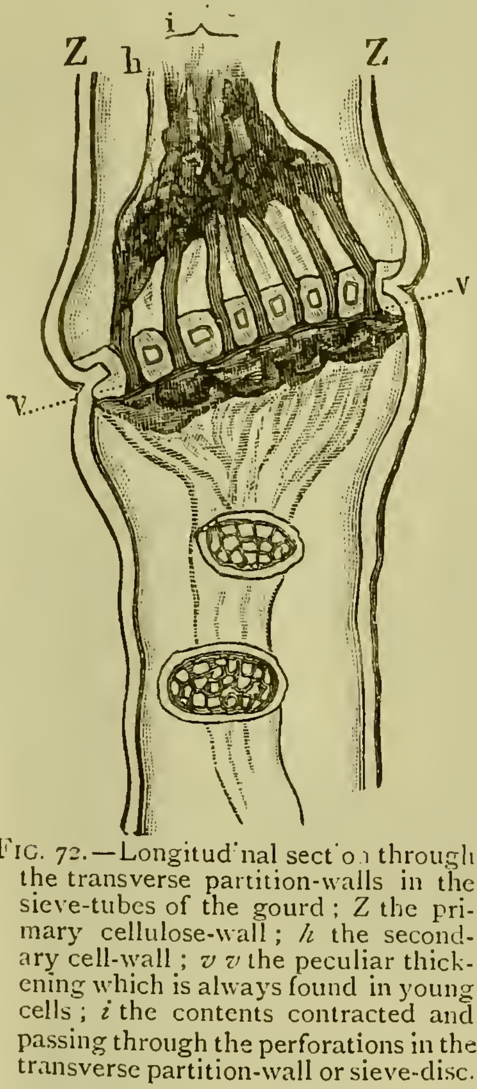

Fig. 72.—Longitudinal section through the transverse partition-walls in the sieve-tubes of the gourd; Z the primary cellulose-wall; *h* the secondary cell-wall; *v v* the peculiar thickening which is always found in young cells; *i* the contents contracted and passing through the perforations in the transverse partition-wall or sieve-disc.

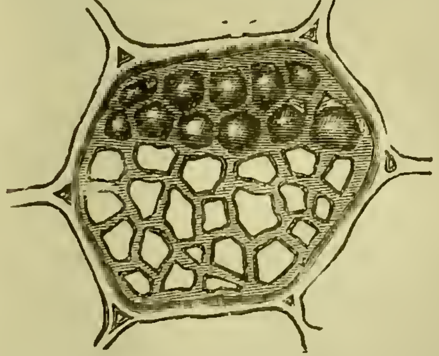

Fig. 73.—Transverse section of a sieve-disc, the upper part represented with the thickening-substance which takes the form of wart-like elevations; the lower part without it. (Strongly magnified.)

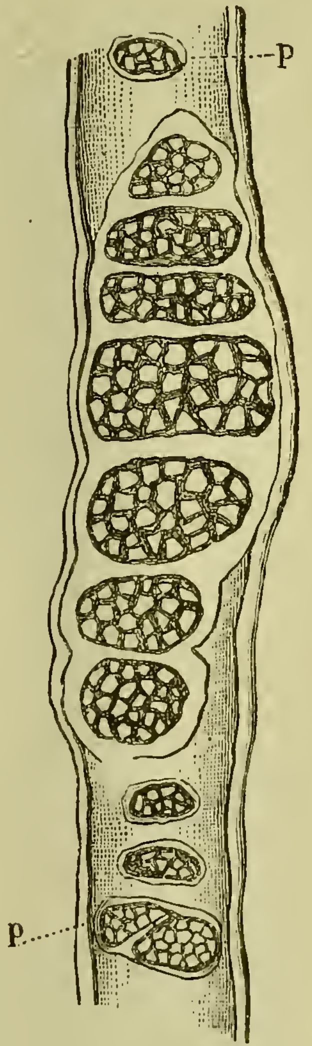

Fig. 74.—Part of a sieve-tube from the lime, *Tilia grandifolia*; *p* the sieve-discs of the radial side-wall. (× about 800.)

ticed cells, the partition-walls of which are not actually perforated, but only thickened in a sieve-like manner. Both contain as a rule a turbid granular sap, are mostly associated in bundles, and take part in the formation of the fibrovascular bundle as *soft bast.*

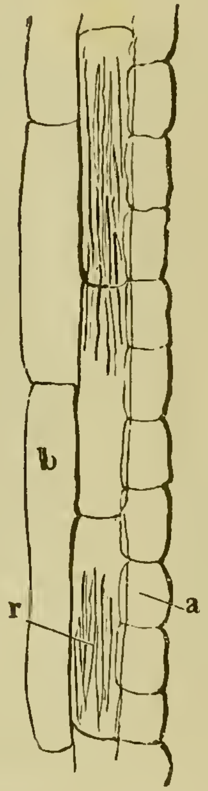

Fig. 75.—Utricular vessel with raphides (r), and contiguous cells a and b, from the stem of a *Tradescantia*. (× 300.)

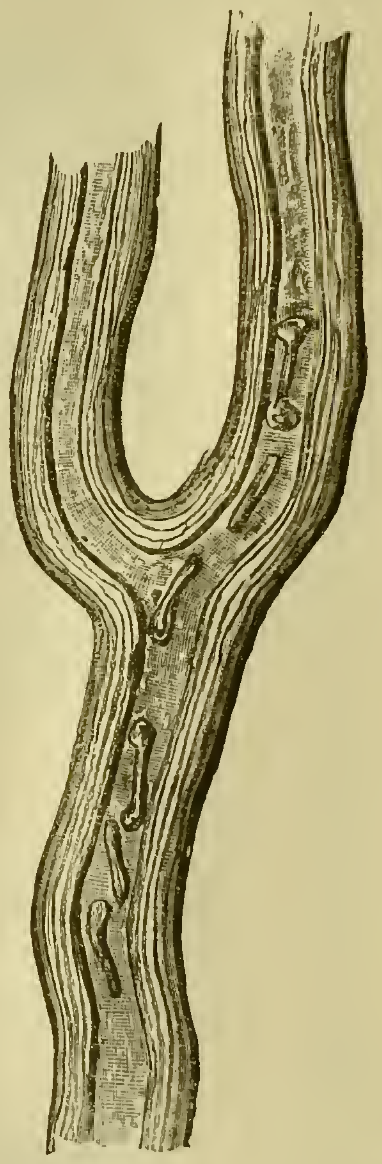

Fig. 76.—Laticiferous vessel from *Euphorbia splendens*, with rod- and bone-shaped granules of starch floating in the latex. (× 250.)

Utricular vessels (Fig. 75) are distinguished from sieve-tubes by their contents and situation. The contents are clear or milky, but always include bundles of acicular crystals (raphides). Their cells, which are moderately thin-walled, (Fig. 75), but otherwise of very various structure, are in contact by their ends, which are either broad or narrow, and often form great systems of tubes, which are never associated into bundles, but run separately and usually in a parallel direction. They occur only in the outer cortex and in the foliar organs in most Monocotyledons and in some Dicotyledons.

Laticiferous vessels are simple or branched tubes, frequently anastomosing, or united into a more or less close network (Figs. 76, 77). They always contain a fluid peculiar to the plant, which is often coloured and frequently of a milky appearance, and is called *latex.* They occur in only a comparatively small number of plants, usually in the cortex between the bast-bundles and the wood, but sometimes also in the outer cortex, the pith, and the wood. They accompany the fibrovascular bundles into the leaves. Nearly related to them are the *laticiferous cells*, long branched simple cells, such as occur in the Euphorbiaceæ, Moraceæ, Asclepiadeæ, *Aconitum*, &c. The latex of different plants contains a great variety of substances: gum, resin,

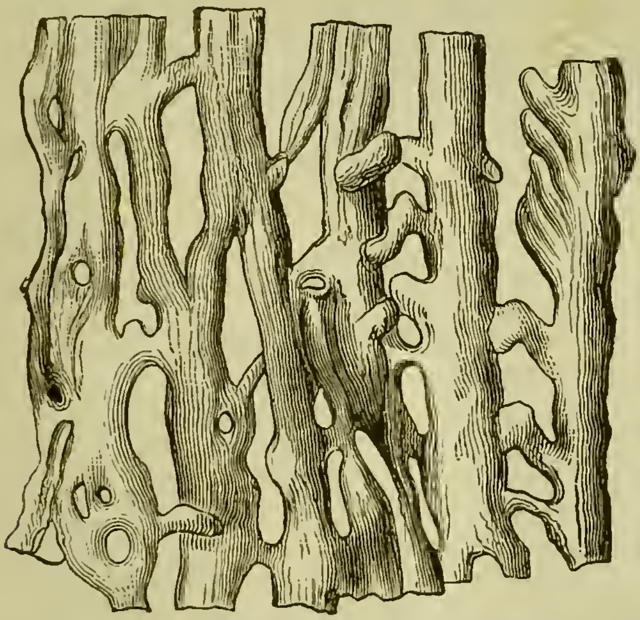

FIG. 77.—Anastomosing laticiferous vessels from a vein of a leaf of the lettuce. (After Hanstein, × 160.)

albumen, opium (in *Papaver somniferum*), caoutchouc (in *Siphonia elastica*, *Isonandra gutta*, and species of *Ficus*), bone-shaped grains of starch (in tropical species of *Euphorbia*), &c. The laticiferous are often distinguished from the utricular vessels only by the absence of raphides. Transitional forms between sieve-tubes and laticiferous vessels occur apparently in the elder and in Aceraceæ. It has not yet been certainly determined whether the latex is a product of excretion or a reserve material.

Closely connected with the laticiferous vessels are certain groups of cells, to which belong the formation and secretion of particular substances, and which have been included under the term the *Secretory System*. In examining them, the chief point to notice is whether the cells themselves contain the secretion formed in them, or whether it has been transferred into the nearest intercellular spaces. It is not always possible, however, to draw a sharp line of demarcation between these two conditions, which may both occur together.

Single cells of this nature, or smaller groups of cells, are called *glands*, while the larger sap-receptacles which extend to a greater length through the parenchyma are termed *passages*. These latter do not always possess a true cell-wall, not being produced by a deliquescence of cell-walls, but by masses of tissue becoming separated from one another, and thus forming a cavity between their cells ; and are therefore true intercellular spaces. [They are then termed *schizogenous* (Figs. 78, 79). Glands are *lysigenous* when resulting from the absorption of a mass of tissue. Glands are also sometimes external organs, when they usually assume the form of *glandular hairs* containing often a fragrant essential oil, as in many Labiatæ. They may then be either simple or compound (see Fig. 92, p. 63).

According to the nature of the substance secreted, these spaces are distinguished into *oil-passages*, as in Umbelliferæ and Compositæ ; *resin-passages*, as in Coniferæ (Figs. 78, 79) ;

gum-passages, as in Cactaceæ, Cycadeæ, Amygdaleæ, &c.; *oil-glands*, in the leaves of *Hypericum perforatum*, species of *Citrus*, &c. ; *camphor-glands* ; and *resin-glands* (Fig. 80). The term honey-glands or *nectaries*, finally, is given to any part of a

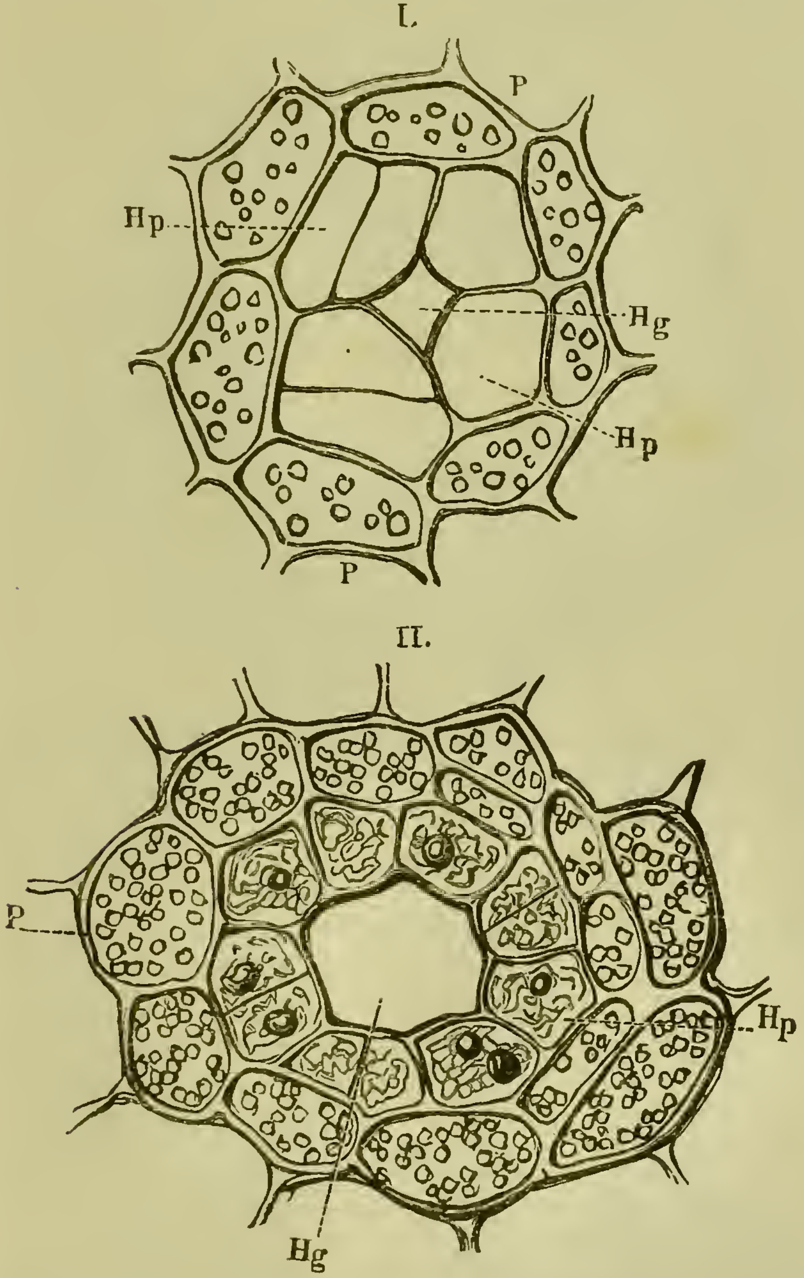

Fig. 78.—Mode of formation of resin-passages ; I. transverse section through a terminal shoot of *Abies excelsa* in process of development ; in the cortex the small group of cells H*p* containing starch-grains and in the act of division has separated from the rest of the cortical cells P which contain chlorophyll ; H*g* the first origin of the resin-passage (× 1000). II. The same from a part more deeply imbedded ; in the young wide resin-passage H*g* the cells which contain resin form only a single layer, and contain, in addition to fine-grained starch, small drops of a volatile oil. (× 800.)

flower or other organ, whatever its structure, which is formed for the secretion of honey or a saccharine fluid (Figs. 265, p. 136; 266, p. 137).

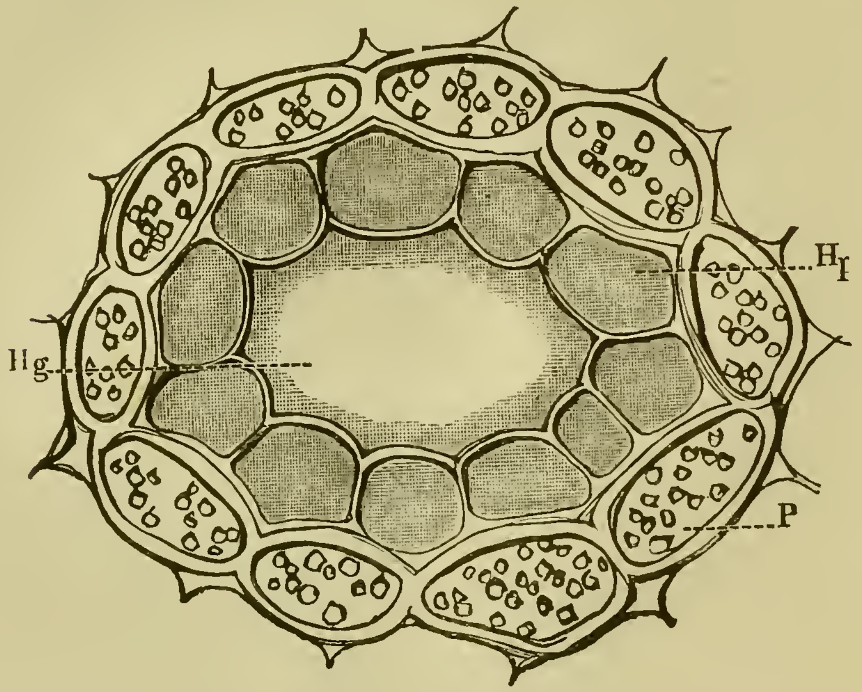

Fig. 79.—Transverse section through a mature resin-passage of *Abies excelsa*; the cavity Hg as well as the thin-walled cells Hp are filled with a semi-fluid resin, while the thick-walled compressed cortical cells P still contain small quantities of starch. (× 800.)

All these separations of masses of tissue are essentially different from the transformations of the cell-wall previously described; although it happens often enough with processes of secretion that cell-walls are ruptured by the pressure of the substances stored up in them, and are carried away along with the waste products (see p. 23).

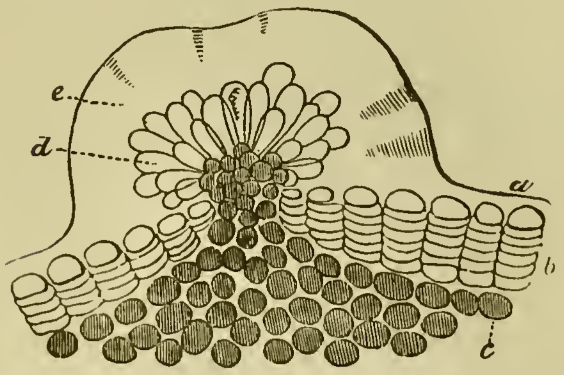

Fig. 80.—Transverse section of a resin-gland from a young birch-twig; *a* epidermal cells; *b* a subjacent layer of cork; *c* collenchymatous cortical tissue; *d* the papillæ of the gland which have secreted the solid resin *e*. (× 100.)

In this connection should be mentioned also certain structures which are possibly of considerable importance for the life of the plant, but which have as yet been but little studied, the overgrowths of *wax* on the surface. These occur especially as a delicate bloom, as for example on the plum, and are sometimes dense agglomerations of rods or needles, as on the leaf of the rye, sometimes simple coatings of granules, as on the 'frosted' leaves of many lilies; sometimes as coatings of rods which stand vertically on the surface of the cuticle, as on the leaves of the banana; or finally as incrustations, as in *Opuntia.*

CHAPTER III.

THE CONSTRUCTION OF THE PLANT OUT OF CELLS.

All plants consist entirely of cells and of the products of the formation and transformation of cells, which are hence called the *elementary organs* of the plant. Only a few plants, belonging to the class of Algæ (Fig. 81) and Fungi, are unicellular; by far the larger number consist of many, and most of an innumerable number of cells, which take part in the construction of the plant. In the simplest multicellular plants the cells are arranged in filaments, *i.e.*, in simple rows one above another, as in the filamentous Algæ and many Fungi (see Fig. 1, p. 7). Those are more highly organised which consist of plates of cells arranged in a single layer, as occurs also in certain Algæ, *e.g.* the Ulvaceæ (Fig. 82). But by far the most common structure is for the plant to be composed of masses of cells radiating from one another in all directions. The course of development of this mass of cells exhibits the following variations in the different sections of the vegetable kingdom.

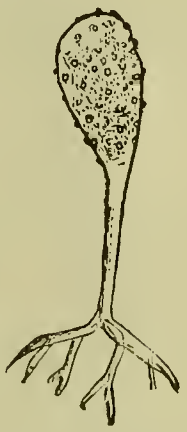

Fig. 81.—A unicellular Alga, *Botrydium Wallrothii.* (See also Fig. 383, p. 252.)

In the higher flowerless plants the mother-cell of an embryo or shoot breaks up into several cells of unequal value. The cell which remains at the apex, or *apical cell*, grows to be like its parent in every respect; and the same process of division is then repeated in it. The building up of the mass of cells of which the plant consists results from the division in all directions of the remaining daughter-cells (Fig. 83 I.).

In flowering plants (Fig. 83 II.) the mode of development is different. The growing end or apex of an organ, such as a root or stem, is here composed of a mass of

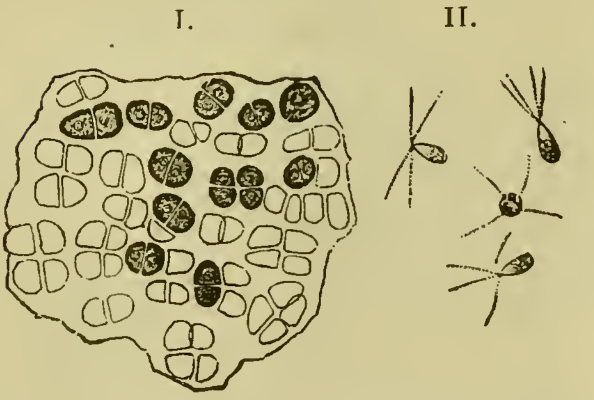

Fig. 82.—I. An Alga, *Ulva bulbosa*, consisting of a single plate of cells; II. Zoospores which have escaped from the empty cells. (× about 300.)

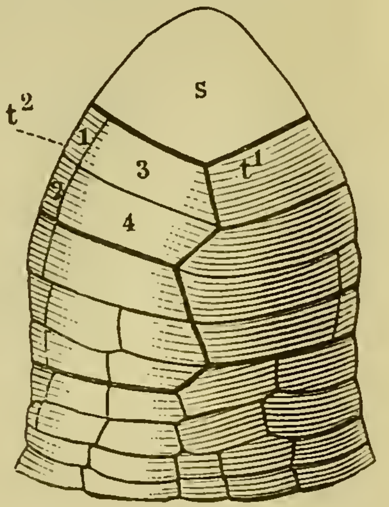

Fig. 83 I.—External view of the exposed apex of the stem of *Equisetum scirpoides*: *s* apical cell; the darker lines indicate the boundaries of the daughter-cells derived from the apical cell, for example, t^1t^2, the latter being again the mother-cell of those marked 1, 2, 3, 4. (×350.)

equivalent cells—known as the *punctum vegetationis* or *growing point*—all capable of division, rich in protoplasm, thin-walled, and without intercellular spaces. From this primary meristem are developed the various kinds of tissue, which may be classed under three heads, the *Fundamental Tissue* or ground-tissue, the *Fibrovascular System*, and the *Epidermal Tissue*.

The order of succession in the formation of the various groups of cells is as follows:—The first independent tissue formed is the primary epidermal tissue or *dermatogen*. The layers of cells lying immediately beneath then begin to develope in a peculiar manner as cortical tissue or *periblem*, the parenchymatous or primary *cortex* being formed from them.

This tissue finally encloses the *plerome* or intermediate tissue, situated not very deep down and laterally from the apex, which breaks up into the *procambium* and the *fundamental tissue.* The procambium is formed in many plants from the entire outer zone of the plerome, while in others it consists of only a few groups of its cells; from the fundamental tissue it is further distinguished by the arrangement and the form of its cells, which are prosenchymatous, while those of the fundamental tissue remain parenchymatous.

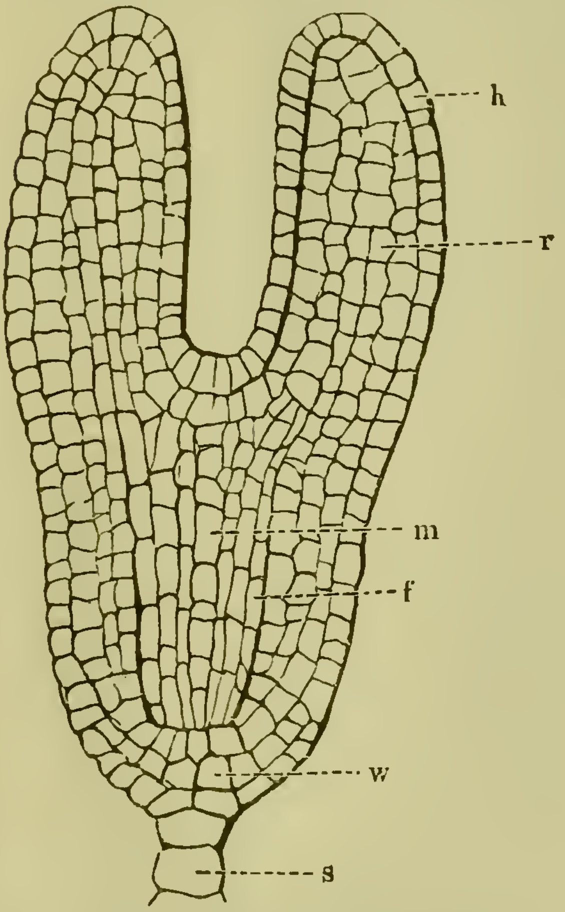

FIG. 83 II.—Longitudinal section (partly diagrammatic) through the young embryo of the shepherd's purse; *h* epidermal tissue (dermatogen); *r* cortical tissue; *m* fundamental tissue; *f* procambium; *w* root-cap; *s* suspensor. (After Hanstein, magnified: see fig. 363, p. 189.)

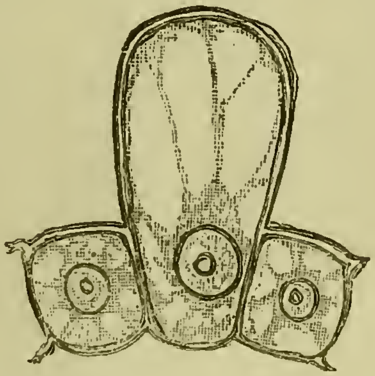

FIG. 84.—Papilla from the young stigma of *Lilium bulbiferum.* (× 660.)

The contrast between the *epidermal tissue* and the subjacent masses of tissue is the more evident the greater the exposure of the part of the plant to air and light, and is also usually more conspicuous in the permanent parts than in those which are more fugitive. In the lowest plants, Algæ, Fungi, and Lichens, and even in the stem of Hepaticæ, the epidermal structure consists only in the outer layers of cells having thicker and firmer cell-walls and smaller cavities than the rest. In some Mosses and in all the more highly organised plants at least one layer of cells specially defined and developed, the *epidermis*, exercises special functions. In true roots, and in many root-like underground stems, as well as in many plants which grow submerged in water, it is less differentiated from the subjacent tissue than is the case in most stems and in leaves.

The outer side of the outermost layer of epidermal cells is gradually transformed into the so-called *cuticle* (see Fig. 21, p. 16), a thin structureless membrane, but little sensitive to external and even to chemical agencies, insoluble, for example, in concentrated sulphuric acid or in potash. The cells of the epidermis usually contain clear or coloured fluids, occasionally crystals, rarely chlorophyll. Their form is very various, but usually tabular or conical, or sometimes even papillæform, *i.e.* projecting on the outside in the form of knobs or bladders. The peculiar appearance of many structures, such as the velvety gloss of petals, is due to papillæ of this nature (Fig. 84). In many cases there lie beneath the epidermis peculiar layers or strings of cells (the *hypoderma*), which are perhaps best included in the epidermal tissue. They consist either of thick-walled prosenchymatous bundles which contribute to the greater firmness and elasticity of the epidermis, as in the aërial portion of the stem of Equiseta, and the acicular leaves of *Pinus pinaster*, or of collenchymatous tissue which tends to increase the difference of tension between the epidermal and the subjacent tissues (see Chap. V.). In plants with a long term of life, and which increase greatly in girth, cork is subsequently formed in the epidermal cells themselves or the subjacent layers of tissue, replacing the true epidermis, which has generally in the meantime perished.

The true epidermis consists, when young, of similar cells which are everywhere closely contiguous. In the course of growth some of these separate from one another, the derivative cells that result from one or more divisions leaving a crevice or pore between them which is called a *stoma* (Fig. 85). These are always[1] enclosed by two or four cells, the *guard-cells*, which are crescent-shaped, and also smaller and with thinner walls than the rest of the cells of the epi-

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[1] Exceptions, however, occur in the case of the Marchantieæ and Rhizocarpeæ.

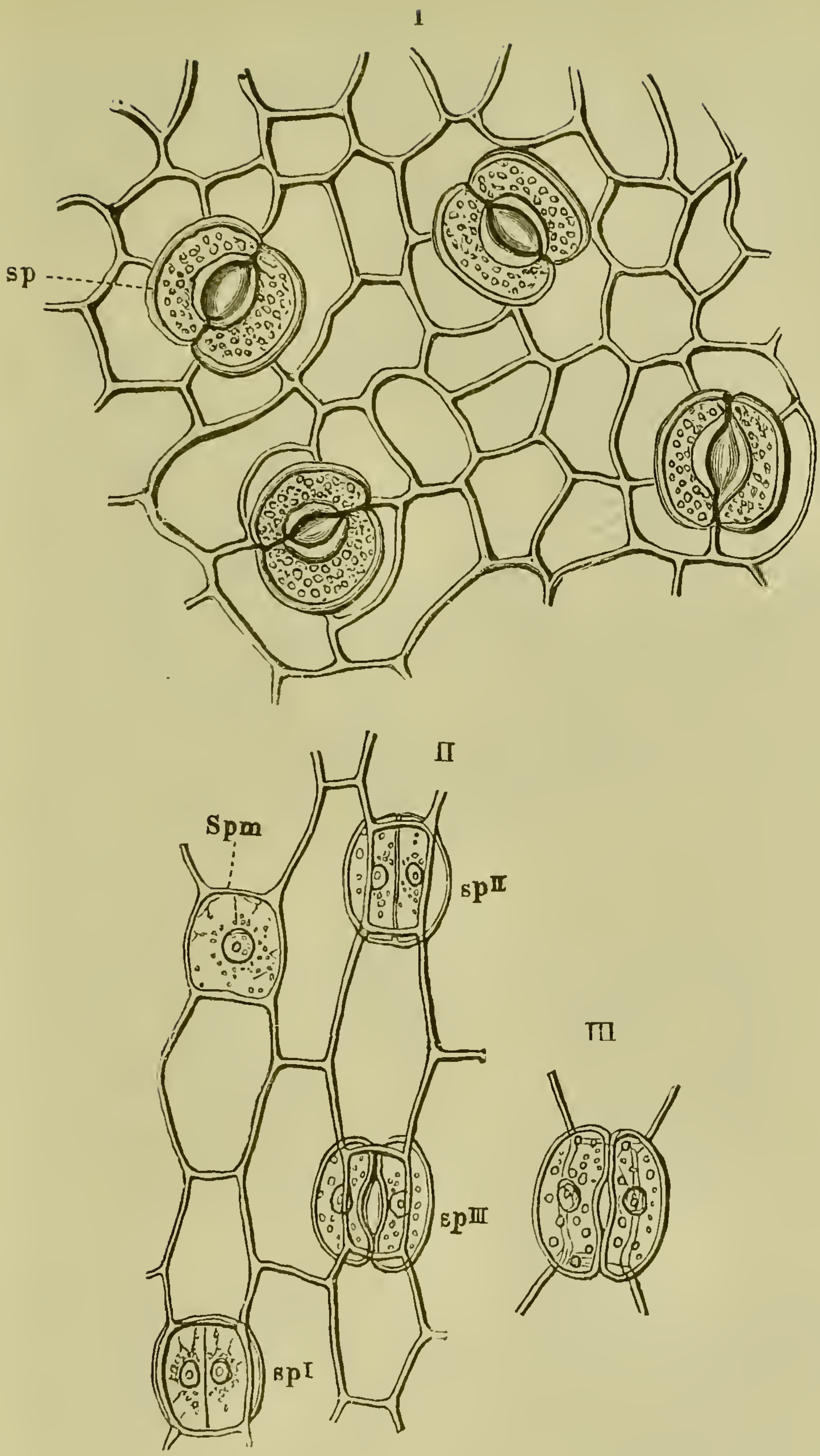


Fig. 85.—I. Horizontal section through the epidermis of the under-side of the leaf of *Euonymus japonicus*, looked at from below; *sp* stomata (× 370); II. Course of development of the stoma of *Arthropodium cirrhatum*; *s p m* mother-cell ready for division; sp^{I}, sp^{II}, sp^{III} successive stages of division; III. Mature stoma. (× 370.)

dermis, and are in addition distinguished from them by containing chlorophyll. This last circumstance gave rise to the earlier view that these cells belong to the subjacent parenchyma of the leaf rather than to the epidermis itself. The stomata are sometimes found at the bottom of a funnel-shaped depression, sometimes on a level with the epidermal cells; while sometimes (Fig. 86) they are even elevated to a higher level. They establish a con-

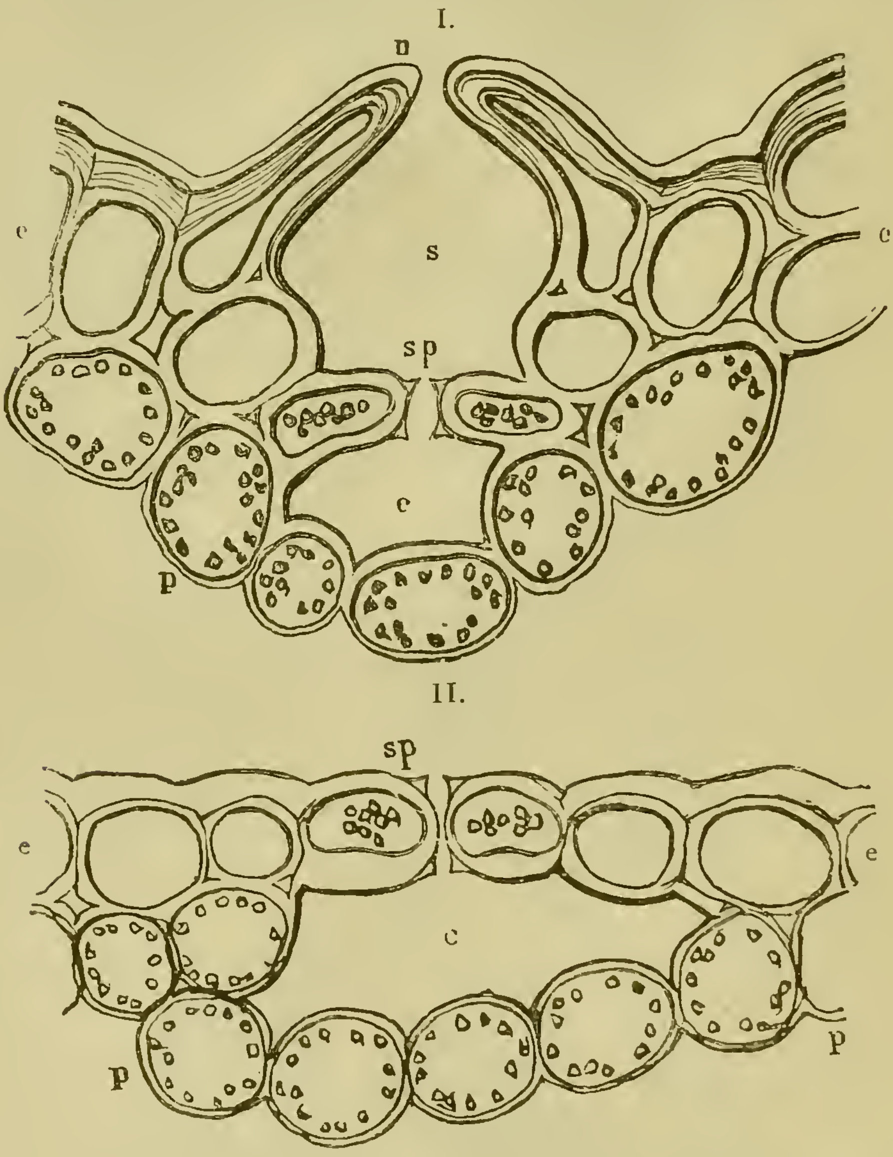


Fig. 86.—I. Transverse section through the epidermis of the leaf of *Cycas revoluta*; *n* elevation of the epidermis; II. Transverse section through the epidermis of the under-side of the leaf of *Polypodium vulgare*; *e e* epidermal cells; *sp* stoma; *p* parenchyma of the leaf; *c* air-cavity. (× 400.)

nection between the atmosphere and the intercellular spaces in the interior filled with air. The interchange of gases which is thus brought about is regulated by the guard-cells being sometimes more and sometimes less close together, so that the pore may be occasionally closed. The perfect stoma may be regarded as consisting of three parts—the anterior or *eisodial*, the posterior or *opisthodial* opening, and the actual fissure which connects these two.

Stomata are found in all the higher plants, from the Hepaticæ upwards. They usually occur in the green parts, more rarely in the coloured petals (as in the hyacinth, crown imperial, &c.), [in the coloured bract or spathe of *Richardia*], and in fruits and seeds (as the tulip). They are wanting in those leaves which grow submerged in water; and in floating leaves occur only on the upper surface. In most Monocotyledons both surfaces of the leaf are provided with stomata, while in Dicotyledons they are generally almost or altogether absent from the upper surface. No general rule can be given for their number nor for their arrangement, which possesses a definite character only in a few groups of plants, as *e.g.* the Equisetaceæ; in Coniferæ and Grasses the arrangement is invariably linear; in the Begonias they are arranged in groups, &c. By far the most common size of the stomata ranges between 0·0002 and 0·0008 mm.; but it may vary, as far as observations have yet been made, between 0·00459 (in *Amaryllis formosissima*), and 0·00011 (in *Amaranthus caudatus*). Stomata are entirely absent from all true roots.

Hair-like bodies or *trichomes* are unquestionably epidermal structures, and may be found even on the youngest parts of the stem, leaves, and roots. Under this category are included hairs, bristles, stinging hairs, prickles, scales, glands, glandular hairs, and the 'paleæ' of Ferns. *Hairs* arise by an elongation of particular epidermal cells (Figs. 87, 89); and if attached to a root are called *root-hairs*. They are either simple or branched, and consist of one or several cells. *Bristles*

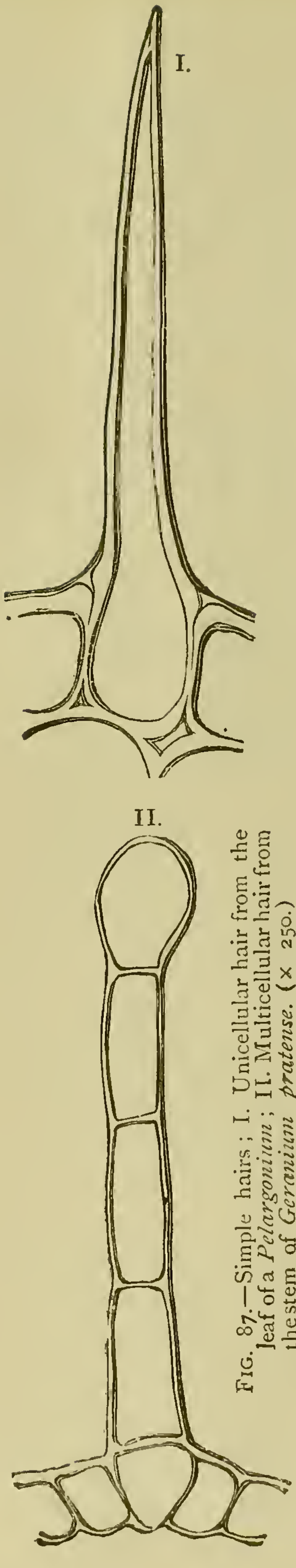


FIG. 87.—Simple hairs; I. Unicellular hair from the leaf of a *Pelargonium*; II. Multicellular hair from the stem of *Geranium pratense*. (× 250.)

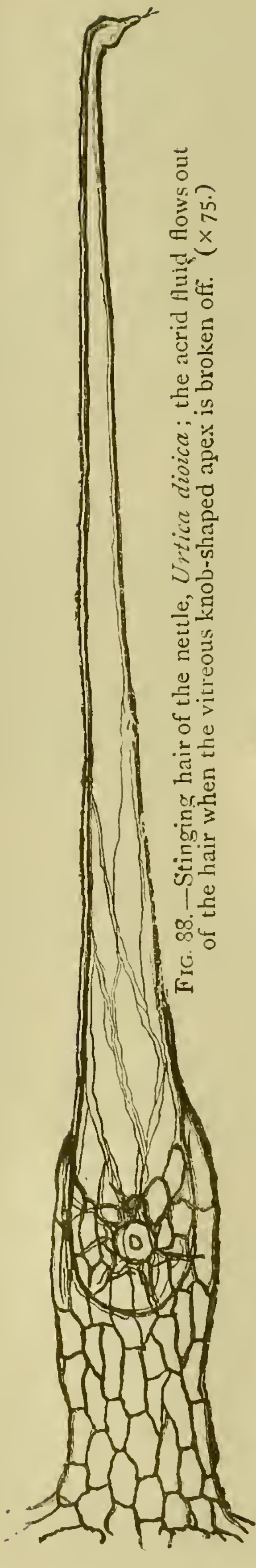


FIG. 88.—Stinging hair of the nettle, *Urtica dioica*; the acrid fluid flows out of the hair when the vitreous knob-shaped apex is broken off. (× 75.)

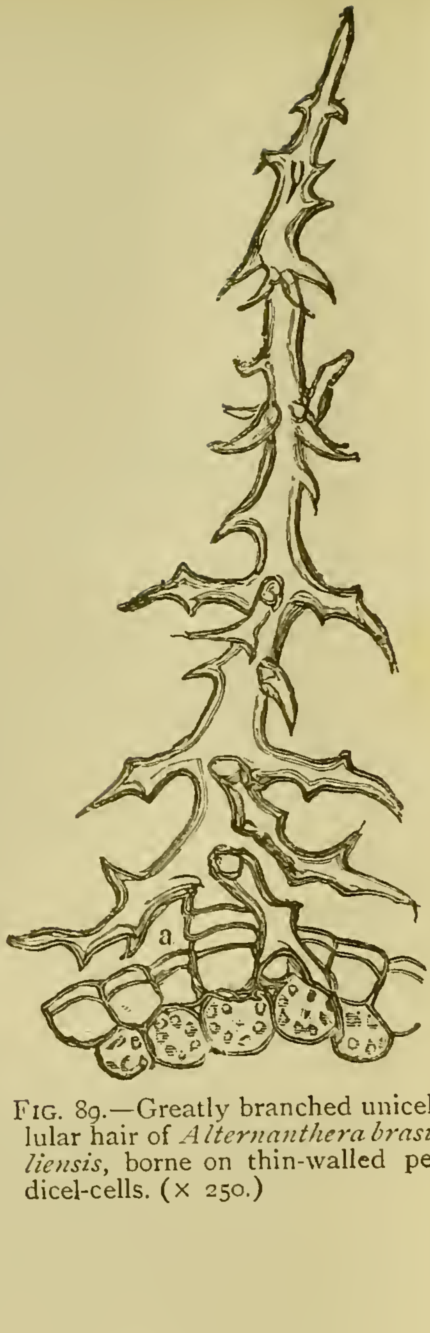


FIG. 89.—Greatly branched unicellular hair of *Alternanthera brasiliensis*, borne on thin-walled pedicel-cells. (× 250.)

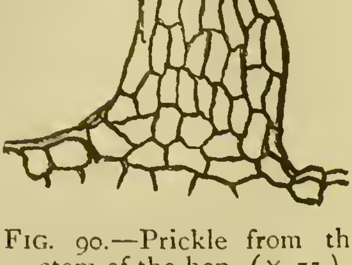


FIG. 90.—Prickle from the stem of the hop. (× 75.)

result from the walls of hairs becoming thicker and woody, *i.e.* by the deposition of lignin. Hairs are not often found in the interior of plants, but occur in the air-passages of Nymphæaceæ. *Stinging-hairs* are such as secrete an acrid irritating fluid which escapes when they are injured; they often stand, as in the stinging-nettle, on a cushion-like base (Fig. 88). *Prickles* (Fig. 90) consist of a great number of thick-walled woody cells. *Scales* [or *peltate hairs*] exhibit a great complication of structure, consisting of an elongated epidermal cell, the pedicel-cell, which bears at its apex a number of cells expanded into the form of a shield (Fig. 91). *Glands* consist of a number of cells puffed out like bladders, in which special fluids of various kinds are secreted. Thus, for example, the leaf-buds are often rendered viscid by a gummy substance, or one composed of a mixture of mucilage and drops of balsam, the first resulting generally from the conversion into mucilage of an epidermal layer lying beneath the cuticle, as in the violet, horse-chestnut, and plum. (See Fig. 80, p. 54.) If glands are elongated into

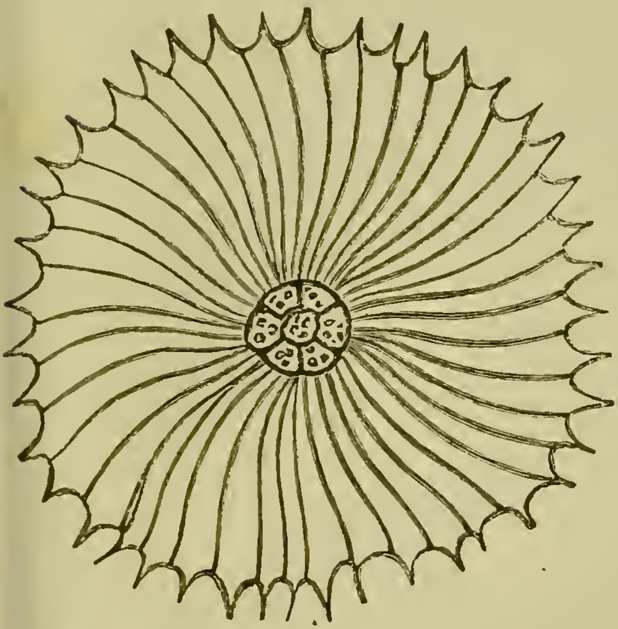


FIG. 91.—Peltate hair from the leaf of *Elæagnus*, seen from above. (× 125.)

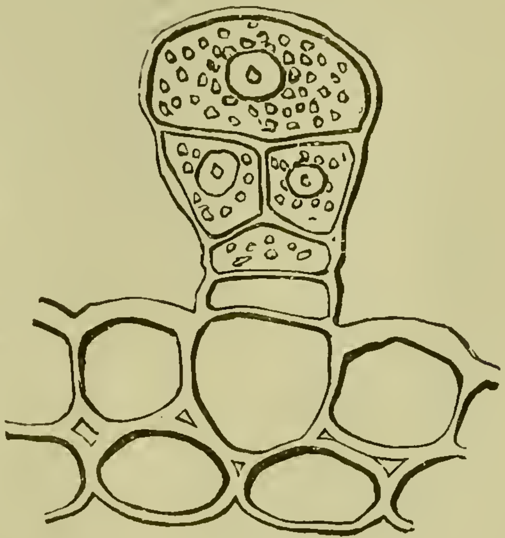


FIG. 92.—Glandular hair from the leaf-stalk of *Lamium purpureum*. (× 370.)

the form of a hair, or borne on the apex of pedicel-cells, they are called *glandular hairs* (Fig. 92).

The *primary cortex* which developes out of the periblem consists commonly of thin-walled succulent parenchyma containing starch or chlorophyll ; other forms of cells, however, as laticiferous and utricular vessels and glands, as well as intercellular passages containing sap, may also occur in it. In some plants masses of cork are found deeply buried in the cortical tissue, or even beneath it, the outer parts then dying, and falling off in the form of bark, as occurs in the grapevine and plane (see Figs. 66, 67, pp. 44, 45).

Every mass of *procambium* consists, in its earliest stage, of similar thin-walled usually prosenchymatous cells, united together without any intercellular spaces. As the mass increases in age, some of the rows of cells become transformed into vascular or bast-cells, and from these as centres the transformation advances of the procambium-cells into permanent cells. Groups are thus formed of particular kinds of cells which, united into strings or bundles, penetrate the rest of the tissue, and as a rule constitute a firm framework, and form the *fibrovascular bundles*, or conducting bundles. These bundles often lie isolated in the fundamental tissue of the plant, as for instance in the veins of the leaves ; but they are generally so crowded and so strongly developed by the continual formation of the tissue of which they are composed, that they finally almost entirely replace the intermediate fundamental tissue, and form almost the whole of the substance of the plant, as is the case in the wood of Dicotyledons and Conifers. The transformation of the procambial cells into permanent cells either continues until they are all so changed, or an inner layer of the procambium remains as the formative *cambium*. As they become older, therefore, the fibrovascular bundles either contain cambium or are destitute of it ; the former being called *open*, the latter *closed* bundles. In the open bundles the cambium is continually forming new layers of permanent cells, and the part of the stem or root is thus constantly increasing in thickness, as is the case in most woody Dicotyledons and Conifers. Closed bundles, on the contrary, such as are found in Cryptogams, Monocotyledons, and a few Dicotyledons, can no longer increase in thickness. The various forms of tissue in a mature fibrovascular bundle may be divided into two

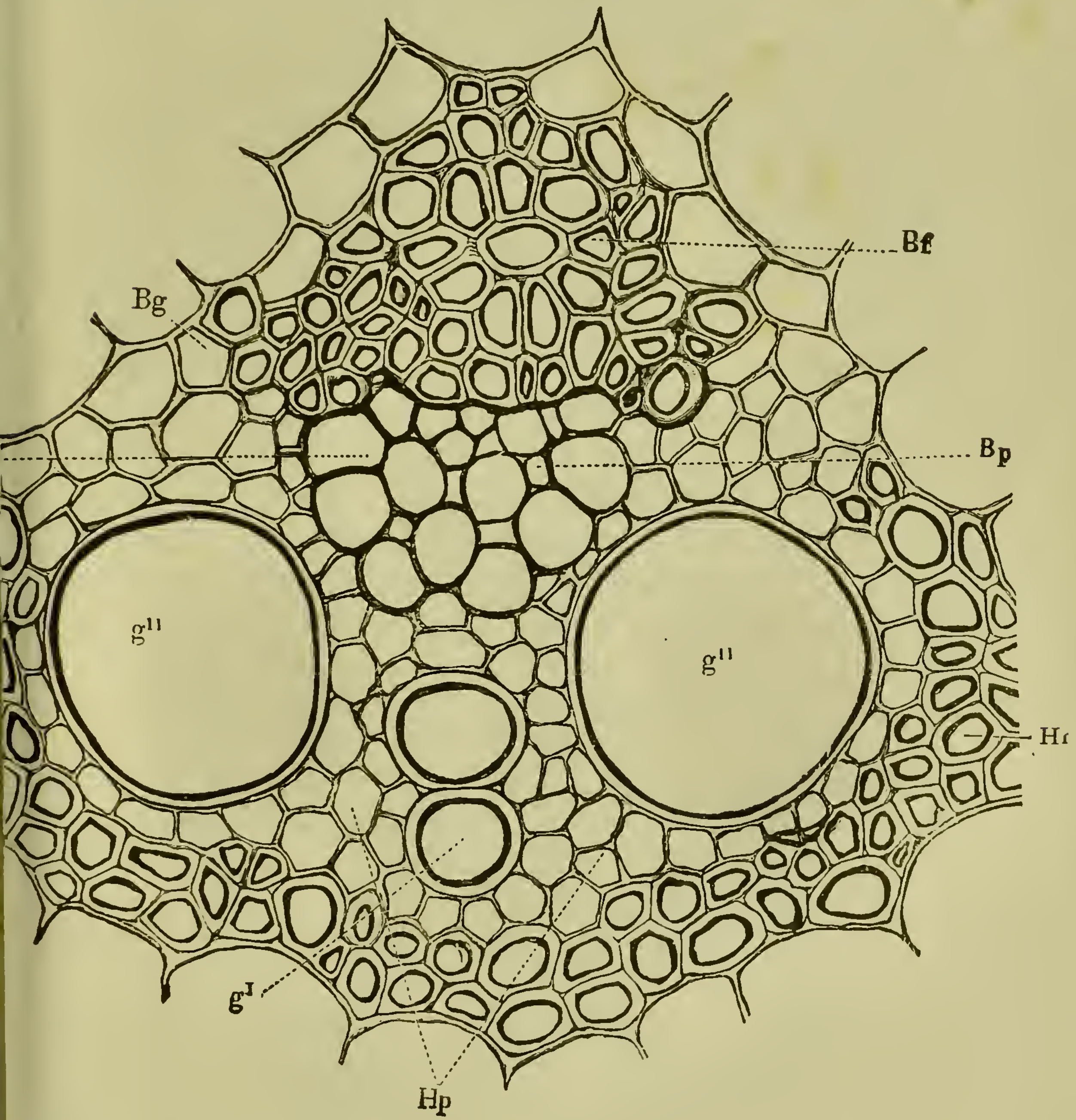


FIG. 93.—Transverse section through a fibrovascular bundle of the sugar-cane; H*p* parenchymatous cells of the xylem; H*f* wood-fibres; g^{I} spiral vessels; g^{II} pitted vessels; B*p* bast-parenchyma; B*g* bast-vessels or sieve-tubes; B*f* bast-fibres. (× 360.)

groups, a woody portion or *xylem*, and a less solid portion, the *bast* or *phloëm* (Fig. 93). The xylem is composed of parenchymatous cells, wood-fibres, vascular cells, and true vessels, the walls of these various elements being generally thickened and lignified. The phloëm, on the other hand, consists of succulent and mostly thin-walled masses of parenchyma and sieve-tubes, in addition to which are usually bast-fibres massively developed and strongly thickened. Any of these elements of the xylem and phloëm may, however, be wanting. The most common arrangement is for the xylem and phloëm in each bundle to lie side by side, the former lying towards the centre, the latter towards the circumference of the stem ; such bundles are termed *collateral.* But in Ferns and some other cases the phloëm completely encloses the xylem, and the bundles are called *concentric.*

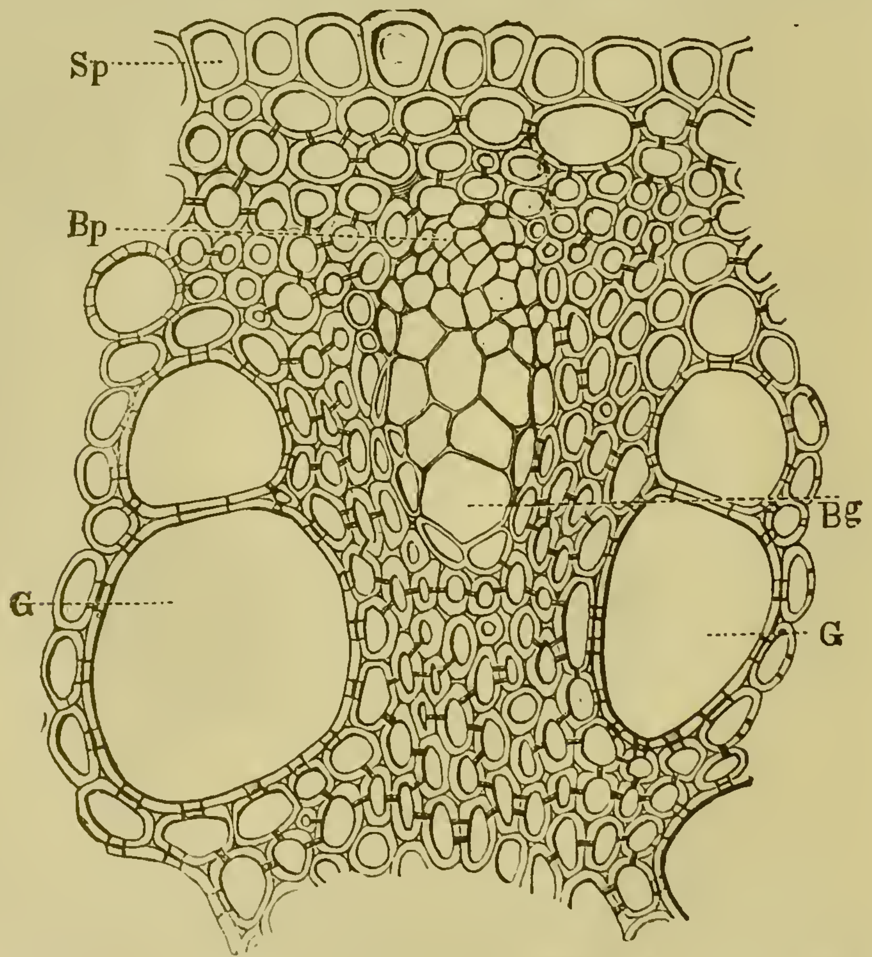
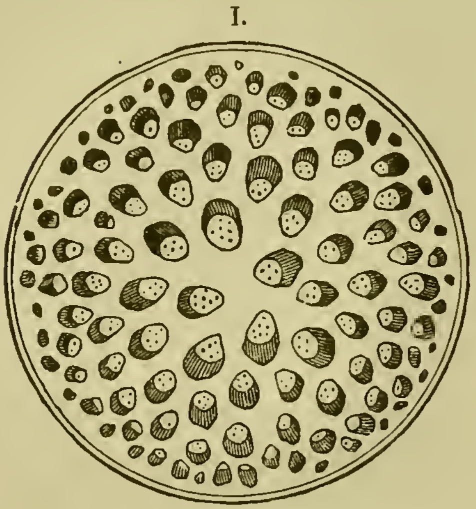


FIG. 94.—Transverse section through the root of sarsaparilla ; S*p* parenchyma of the root-sheath ; B*p* bast-parenchyma ; B*g* bast-vessels ; G vessels. (× 200.)

Narrow thin-walled elongated succulent cells, often found in connection with the sieve-tubes, but whose nature is not yet fully understood, have been termed *cambiform tissue* or permanent cambium. Cambiform tissue, latticed cells, and sieve-tubes form, together with thin-walled parenchyma, the *soft bast*, in contrast to the true bast, which is prosenchymatous. In many plants a ring of cells, often with strongly-thickened and lignified walls, the *vascular bundle-sheath*, is developed either only on the outside of the bast, or round the entire bundle, or very commonly round the whole mass of fibrovascular bundles. This is especially the case in roots, this layer of cells being there called the *root-sheath* or *coleorhiza* (Fig. 94). The separate cells of this organ are as a rule developed in a very characteristic manner.

The further development of the fibrovascular bundles is very characteristic of the different classes of plants, as is also the arrangement of the various elements in a transverse section of a bundle. Thallophytes and Characeæ have no fibrovascular bundles; and in Muscineæ they are either not developed at all or only in a rudimentary manner. These plants are therefore comprised under the designation *Cellular Plants*; the whole of the remainder, Vascular Cryptogams and Phanerogams, being termed *Vascular Plants.*

The *fundamental tissue* very commonly consists of thin-walled succulent parenchyma containing starch; but other forms of cells may also enter into its composition. In those plants which have no fibrovascular bundles the whole of the interior of the plant may be regarded as fundamental tissue. In other plants it fills up the spaces between the fibrovascular bundles and within the epidermis. Where the fibrovascular bundles are closed, Vascular Cryptogams and Endogens, and cannot therefore increase in thickness, this tissue is generally developed to the greatest extent (Fig. 95, I). In the woody portions, *i.e.* the stem and root, of Conifers and Dicotyledons, the fibrovascular bundles of which are open, it occupies a less considerable portion of the entire structure. In the greater number of such stems it forms a central *pith*, which is connected with the bark by more or less largely developed portions of cellular tissue, the *medullary rays*, (Fig. 95, II., S^{I}). In by far the greater number of roots the fibrovascular bundles, on the contrary, form a cylinder destitute of pith and reaching the centre, so that the fundamental tissue is developed only as primary cortex.



[The fundamental tissue of the leaf, consisting of cells containing chlorophyll, and penetrated by the fibrovascular bundles, is known as the *mesophyll.* The outermost of these cells, nearest to the epidermis, are often greatly elongated in a direction at right-angles to the surface, and are called *palisade cells.*]

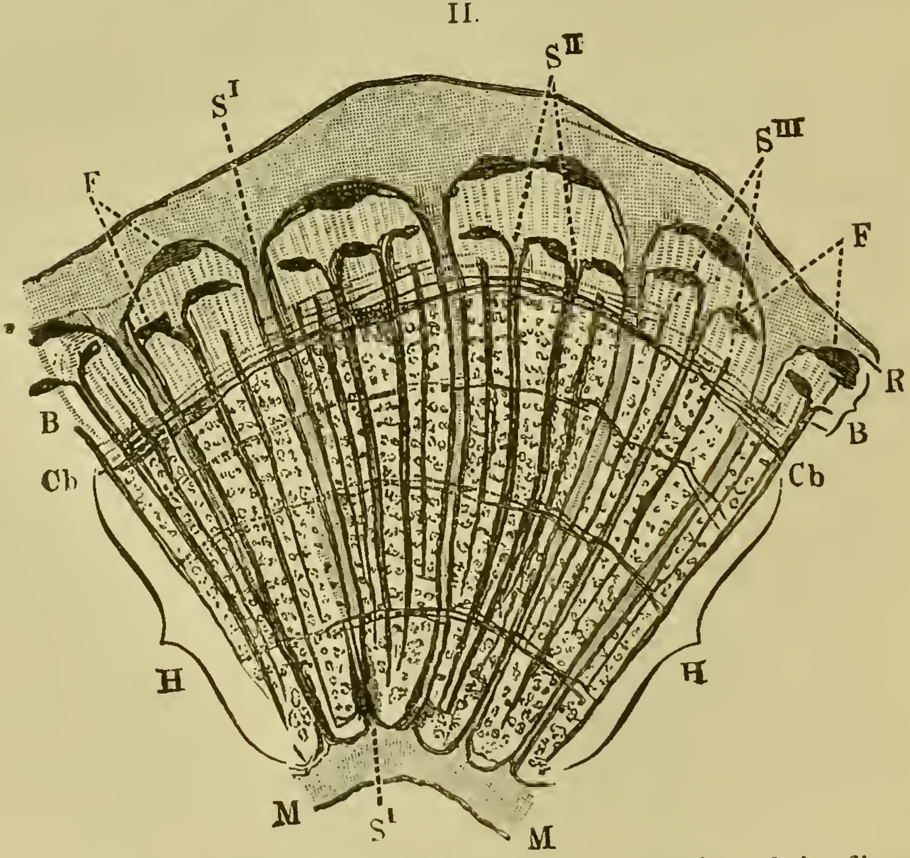


Fig. 95.—I. Diagrammatic representation of the distribution of the fibrovascular bundles in the transverse section of a palm-stem. II. Portion of the transverse section through a shoot of ivy four years old; R cortex; B bast-bundles; H wood, in which the four annual rings are distinctly visible; M pith; S^{1} medullary rays; F bast-fibres; C *b* cambium; S^{II} primary; S^{III} secondary bundles.

The various elements, the different forms of cells, tissues, and fibrovascular bundles, are always arranged in each species in a thoroughly characteristic manner; and from this, as well as from the nature of the elements themselves that are present, it is very often possible to recognise the species from a small fragment of the plant. Only in comparatively few cases are the plants adapted at once for microscopical examination. When they are not so adapted, they must be dissected into small transparent pieces; and the direction in which the section has been made must also be noted. In order to examine, for example, the structure of a branch, preparations must be made, taken from it principally in the following three ways (Fig. 96): in the *transverse section a b* at right angles to the axis of growth *mn*, the *longitudinal section cd* through the axis, and the *tangential section ef* parallel to it. Sections in other directions, as the *oblique gh*, are only occasionally needed. In certain cases it is also requisite, in order to make the preparation transparent or decompose it into its separate elements, to macerate it, especially when it is desired to determine the form and connection of the individual cells. We have here no space to enter into a detailed account of the application of the microscope to botanical investigation, and can only refer to the works of Dippel, Harting, Nägeli and Schwendener, and Schacht.

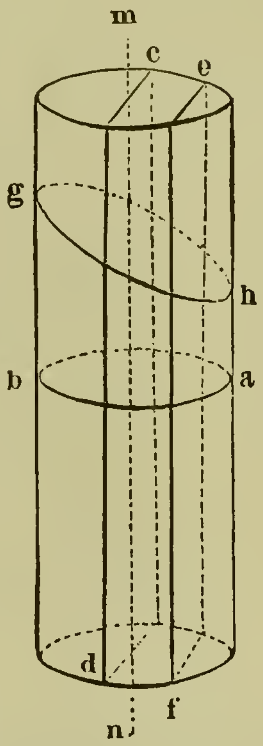


Fig. 96.—Diagram representing the various sections of a stem.

CHAPTER IV.

THE EXTERNAL FORM OF PLANTS.

In the plants of lowest organisation, Algæ, Fungi, and Lichens, the contrast which is so manifest in those more highly developed between an axis (stem and root) and the lateral organs (leaves), is altogether wanting. With reference to this point, the vegetable kingdom is therefore divided primarily into plants without an axis or *Thallophytes*, and plants with an axis or *Cormophytes*, the term *thallus* being applied to an undifferentiated foliar structure.

The external differentiation of the parts in cormophytes can be very well seen in a germinating pea. If the leathery skin [or testa] is stripped from a pea which has been soaked in water, two large fleshy masses are seen, the *cotyledons*, enclosing a small cylindrical body, the *axis* (Figs. 97, 98), which bears two minute leaves at its extremity; the cotyledons and axis together constituting the *embryo*. If this pea had been planted in the ground, there would have been formed under favourable circumstances, from the growth of the axis of the embryo, the *stem* directed upwards and the *root* directed downwards. When the seed germinates (Fig. 99), a smaller or larger number of lateral organs, the *leaves* (*c d*), develope, but only on the ascending portion of the axis, not on the root. The form of the leaves is very various according to their function in the life of the plant; certain of them unite, in the form of floral leaves, together with the stem, to produce the *flower*. From a particular part of the flower is developed the *fruit*, within which are produced the *seeds* destined for the reproduction of the species. Epidermal structures (trichomes), finally, clothe the surface at different parts.

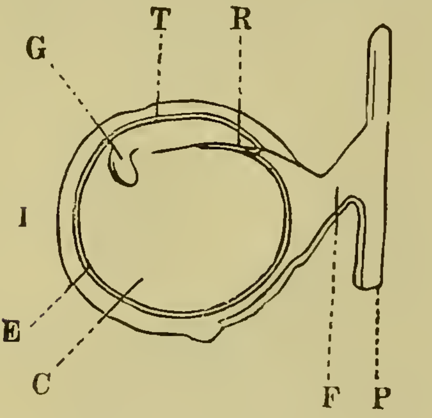


FIG. 97.—Pea, with its testa cut through; C cotyledons; G the plumule enveloped in minute leaves; R radicle; T axis of the embryo; I outer, E inner integument; F funiculus; P part of the pericarp (diagrammatic).

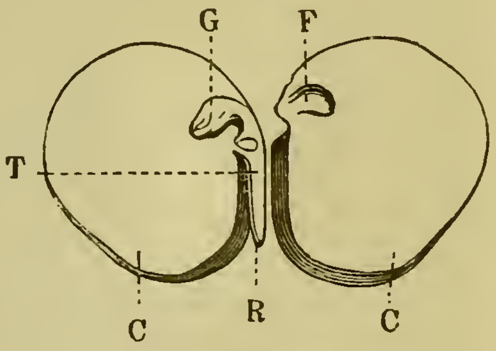


FIG. 98.—Pea split open and with the testa removed; F small cavity in which the plumule or apex of the stem lay; the other letters as in Fig. 97 (somewhat magnified).

If the history of development of an embryo, as that of the pea, is examined more closely, it is found that from a uniformly plastic mass of similar cells the root is developed downwards, and the stem-bud upwards. The stem-bud, or *plumule*, is divided from the outset into stem and leaves. The leaves therefore do not grow on a stem already formed; on the contrary, they constitute from the first, together with the stem, a hemispherical body consisting of primary parenchyma, which then becomes lobed. It is therefore impossible to draw accurate lines of demarcation between the three main organs of the plant, the *root*, *stem*, and *leaf*. The stem is distinguished from the root only by

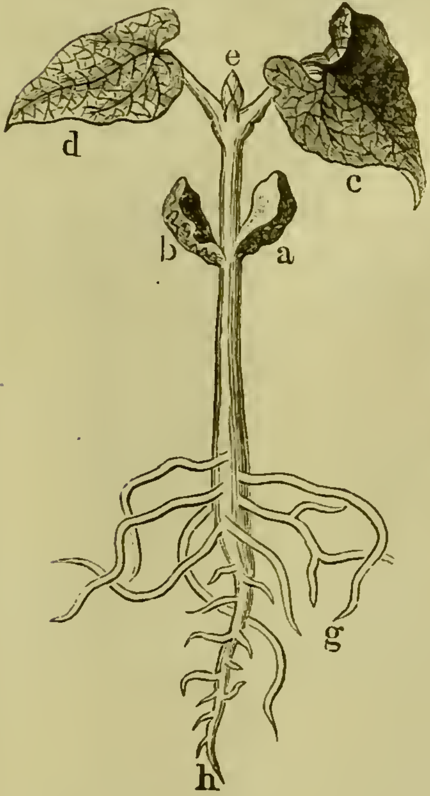


FIG. 99.—Germinating bean; *a b* cotyledons; *c d* leaves; *e* terminal bud; *h* primary root; *g* lateral roots.

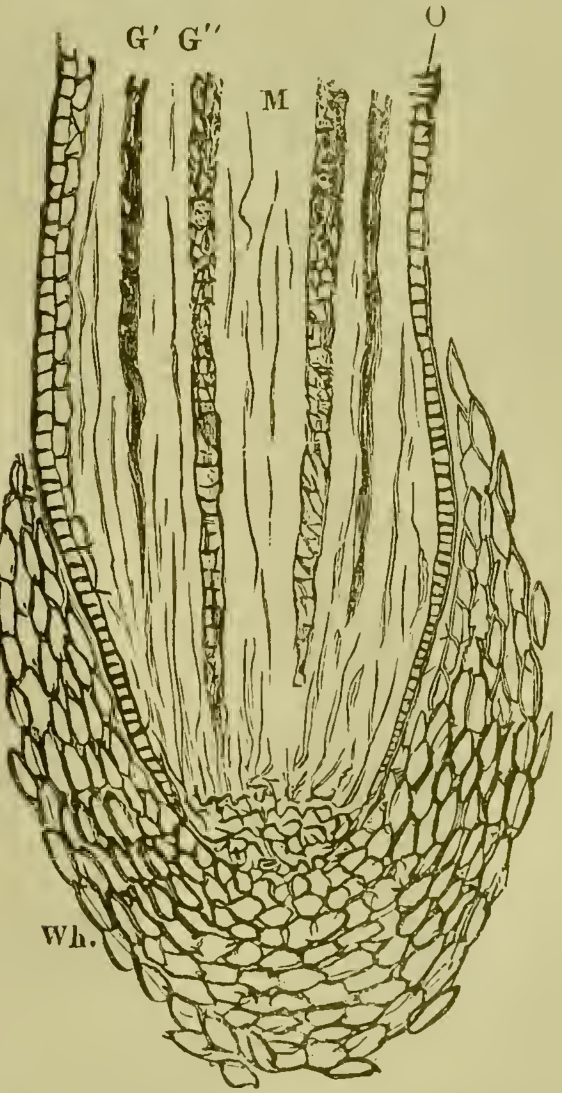


FIG. 100.—Longitudinal section through the apex of a root of *Aspidistra elatior*; W *h* root-cap; M pith; O epidermis; G' narrow spiral vessels; G'' broad reticulate vessels. (× 75).

bearing leaves, while the latter does not. Leaves are lateral [or appendicular] organs which do not possess any capacity of development of their own, and which may therefore be regarded in many respects as appendages attached to the entire organism, not possessing an independent life. It follows therefore naturally that the leaves and axis are subject to different laws of growth :—the axis grows at its apex, and the leaves at their base where they are attached to the axis. New leaves are developed only at the extreme end of the branch. The roots, on the other hand, have no power of forming leaves, because the outermost cells of their growing points die very early, and then cover it in the form of a cap (Fig. 100, w*h*). Beneath this *root-cap*, as it is termed, the production of new cells continues; while the cap itself acts as a protecting shield to the root when it penetrates into the hard soil. The growth in length of roots ceases therefore so near their apex that the portion which is at any time actually increasing in length is usually only a few millimetres long.

In the remainder of this chapter no reference will be made to flowerless plants, but only to flowering plants or Phanerogams, since the morphology of the former is so closely connected with their classification that it will be better spoken of under that head. Much, however, that is now described applies equally to both classes [at least to those Cryptogams which are also cormophytes], especially all that relates to the branching of the axis, the buds, phyllotaxis, the forms of leaves, secondary organs, &c.

THE ROOT.

The Root is that part of the plant which, usually growing downwards, fixes it into the ground, and absorbs nutriment out of the soil. It bears at its apex a root-cap, and never developes leaves.

Some plants have certain characteristic kinds of roots which do not in all respects answer the description given above. Thus *clasping roots*, as those of the ivy, often penetrate laterally into trees, rocks, or walls.

The *aërial roots* of tropical Orchids, Pandani [and Aroids] depend from the stem and branches, and in many cases never reach the ground. The *floating* primary root of *Trapa*, which germinates while lying on the ground, at first ascends, and remains in that direction. The *aquatic roots* of floating plants like *Lemna* never attempt to become fixed in the ground; or, as in the case of *Cicuta*, assume a totally different appearance. The '*haustoria*' of parasitic plants, finally, penetrate into the stem of their hosts, and feed on their sap. The characters which include all roots, and distinguish them from stems, are the absence of leaves, and the presence of a root-cap at their extremity.

By the *primary root* is meant that which is formed by the downward elongation of the axis of the embryo, and which is therefore in a line with the stem. It is called a *tap-root* (Fig. 101) when it is thicker than the branches which proceed from it; and may then be *fusiform* or spindle-shaped (Fig. 102), *napiform* or turnip-shaped (Fig. 103), *premorse*, *i.e.* suddenly ending with a blunt point, as if bitten off, as in *Plantago major* [this is, however, strictly a rhizome], *filiform* (Fig. 104), or *cylindrical.*

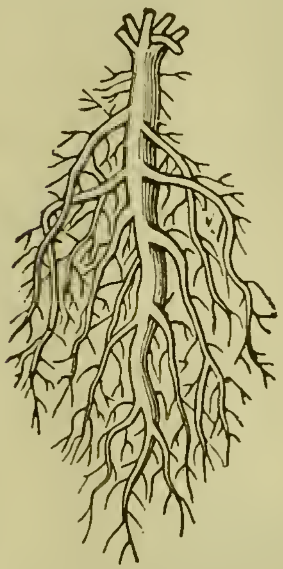


FIG. 101.—Diagram of a tap-root.

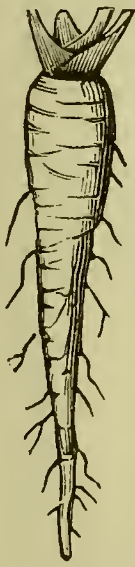


FIG. 102.—Fusiform root of the carrot.

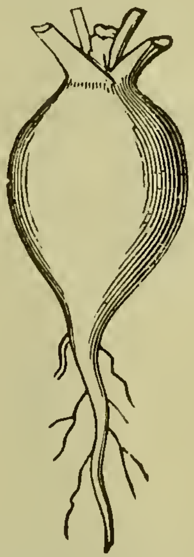


FIG. 103.—Napiform root of the radish.

Secondary or lateral *roots* are those which spring laterally from the stem [or from the primary root], as the clasping roots of ivy. In many plants in which the primary root remains undeveloped, and dies off shortly after germination, it is replaced by a number of secondary roots developed from the lower extremity of the stem. In Grasses, for example, these roots are filiform, and are then called *fibrous roots* (Fig. 105); but not unfrequently some of them become *tuberous* [*i.e.* much swollen at intervals, or in the middle]; and

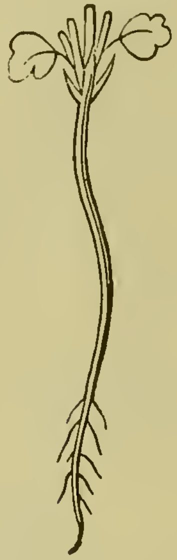


FIG. 104.—Diagram of filiform root.

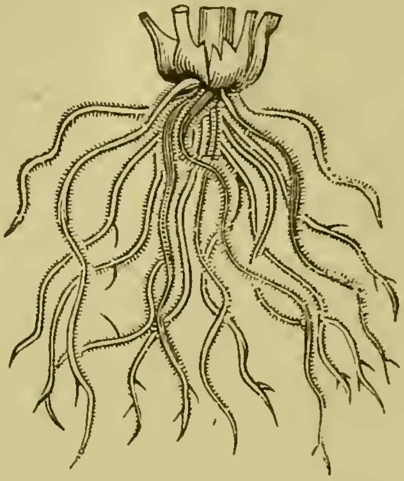


FIG. 105.—Fibrous root of a grass.

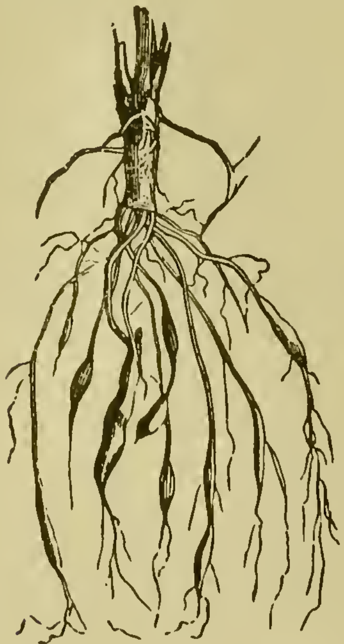


FIG. 106.—Tuberous fasciculated root of *Spiræa filipendula*.

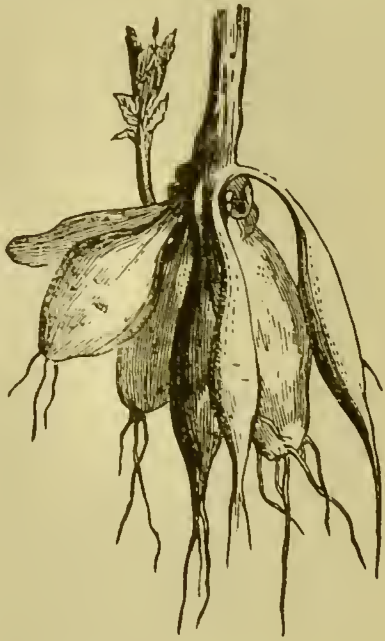


FIG. 107.—Tuberous fasciculated root of the dahlia.

they are then called *fasciculated* (Figs. 106, 107). All roots are more or less branched, and are often clothed with extremely delicate *root-hairs.* If the branches of the root run principally near the surface of the ground, they are called *creeping roots.* With reference to their texture, they may be divided into woody and fleshy.[1]

THE STEM.

The Stem, in its various forms—to which a great variety of names are given from its diverse appearance, though in essential points always the same organ—is that part of the plant which is constructed for the purpose of bearing the leaves, flowers, and fruits.

In ordinary language the term is applied to those parts of the plant only which are above ground. But a closer examination shows that many plants possess organs which must, in accordance with their function, be considered stems, but which nevertheless remain, during the whole of their existence, below the surface of the ground; and these are called *underground stems.* There are some plants which are apparently stemless or *acaulescent*, with radical leaves only ; but this results from the stem remaining very short and undeveloped in proportion to the root and leaves, and being therefore overlooked. Examples occur in *Plantago*, the turnip, [primrose], &c. There is often a portion of the stem below the first pair of leaves, or cotyledonary leaves, intermediate between them and the root ; this is then known as the *tigellum* or caulicle.

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[1] [Any root which results from the development of the radicle or lower extremity of the axis of the embryo is a *normal root*; the term *adventitious root* being applied to those of any other origin, *i.e.* from the stem, either below or above ground. Aërial roots are usually adventitious, and their purpose is generally to absorb moisture from the atmosphere. The aërial roots, however, of the banyan, *Ficus indica*, at length reach the ground, assume the character of trunks, and give to a single tree the aspect of a grove; while those of the mangrove, *Rhizophora*, which also reach the ground, are true normal roots, resulting from the germination of the seed while the fruit is still attached to the tree. The roots of Monocotyledons are usually adventitious, the radicle rarely being developed, as are also those of Cryptogams. The roots of parasites, which derive their nourishment from the living tissue of their hosts, may be normal as in the mistletoe, *Viscum album*, or adventitious as in the dodder, *Cuscuta*, where the original normal root which strikes into the soil dies away, and the plant subsequently attaches itself to its host by 'haustoria.' True roots do occasionally, but very rarely, produce leaf-buds (see p. 82). The function of the root-hairs is the absorption of liquid nutriment from the soil.—Ed.]

Those stems which spring, on germination, directly from the axis of the embryo [*i.e.* from its upper extremity or *plumule*] are called *primary stems*, and their ramifications *secondary* or lateral stems, or branches. The position of the branches on the primary axis determines what is called the habit of the plant. They are said to be *verticillate* or whorled when several spring from the primary stem at the same height, as in *Equisetum* ; *opposite* [as in the elder] when two opposite branches are always found at the same height ; *decussate* when each opposite pair is at right angles to those immediately above and below it, as in the lavender ; *dichotomous* when the stem repeatedly divides into two branches of equal thickness, as in the mistletoe ; *scattered* when the arrangement of the branches is apparently irregular. It sometimes happens, especially in the inflorescence of rushes, that a lateral branch completely takes the place of a primary axis the development of which has been suppressed, and continues its growth in nearly the same direction ; and such a branch, which therefore consists of several successive secondary axes, is a *sympodium*. The part of a stem which intervenes between two leaves is an *internode*, [and the part from which a leaf springs is a *node*]. The length of life of the stem and roots may be only a single year, *annual* ; two years, *biennial* ; or a number of years, *perennial*.

The most completely developed form of the aërial (above-ground) stem, the woody stem or *trunk*, is the characteristic of *trees* and *shrubs*. If the lower and smaller part of the stem is woody, while the upper and larger part dies off every year, as in *Salvia officinalis*, the stem is *suffruticose.* In palms and some other trees the trunk is simple and unbranched, and is then a *caudex;* when the stem remains weak and does not become woody, it is *herbaceous*, and then but rarely, as in many succulent cacti, is perennial. The *scape* is a leafless stem bearing only flowers, springing from a flat base, or belonging to a so-called stemless plant; it may bear only a single flower as in the tulip, or several as in the lily-of-the-valley (Fig. 108), hyacinth, and *Plantago.* The *culm* is a stem the internodes of which are separated by thickened nodes, as in grasses, and is usually hollow and unbranched; the *calamus* on the contrary, as in rushes, is pithy and without thickened nodes. Sometimes, as in the strawberry, the stem sends out *runners*, *i.e.* branches which run along the ground, put out adventitious roots from their nodes or at their extremity, and develope there a perfect plant.

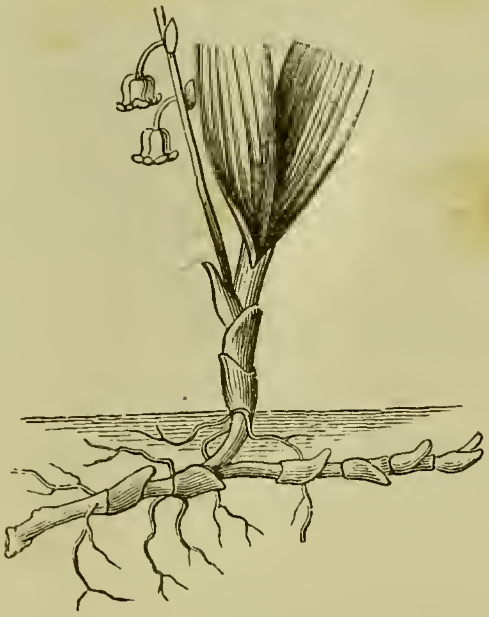

FIG. 108. — Rhizome and scape of the lily-of-the-valley, *Convallaria majalis* (reduced).

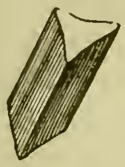

FIG. 109.—Section of triangular stem.

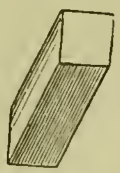

FIG. 110.—Section of square stem.

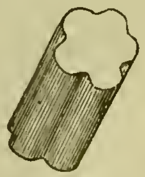

FIG. 111.—Section of 5-ribbed stem.

If a stem is cut through transversely, the figure of the section is usually more or less round or cylindrical, or is compressed into an elliptical form; but it is often angular, for instance triangular in *Carex* (Fig. 109), square in Labiatæ (Fig. 110), five-ribbed (Fig. 111), &c.

The form of the stem is usually more or less cylindrical, but often globose, two-edged, as in several species of *Cactus*, filiform as in flax, or leaf-like as in some species of Cactus and *Ruscus* (Fig. 112).[1]

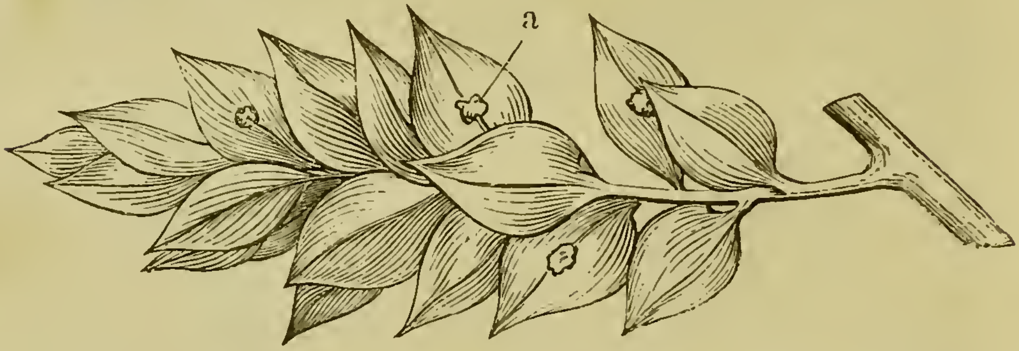

FIG. 112.—Leaf-like branch or phylloclade of *Ruscus aculeatus* ; *a*, flower.

In reference to its position, the stem may be erect, pendulous as in the sunflower, nodding as in *Carduus nutans*, decumbent, flexuose, creeping, where it puts out adventitious

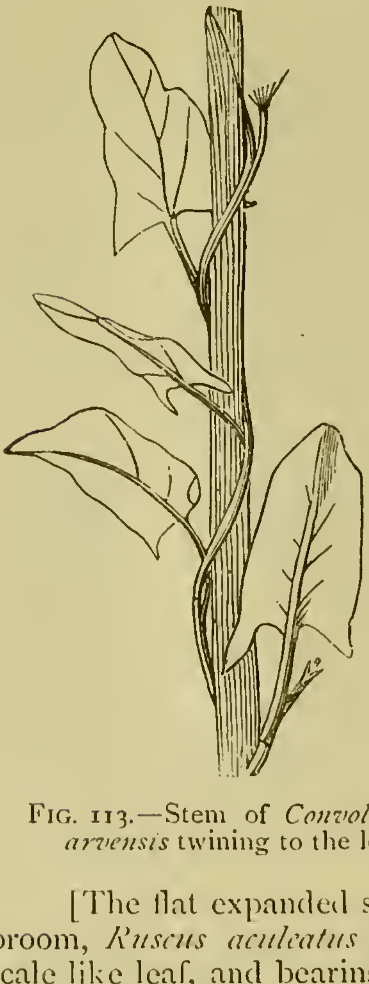

FIG. 113.—Stem of *Convolvulus arvensis* twining to the left.

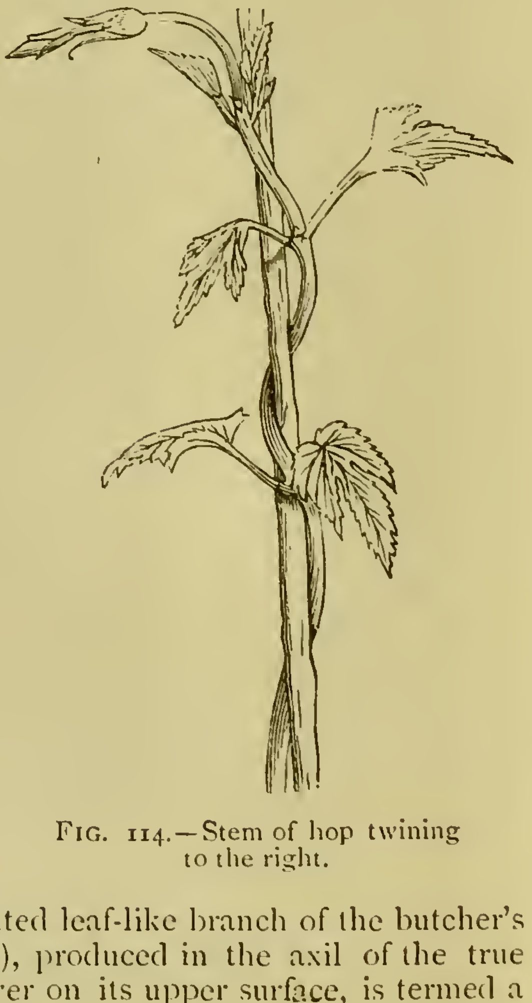

FIG. 114.—Stem of hop twining to the right.

[The flat expanded sharp-pointed leaf-like branch of the butcher's broom, *Ruscus aculeatus* (Fig. 112), produced in the axil of the true scale like leaf, and bearing the flower on its upper surface, is termed a *phylloclade*. – ED.]

roots from its under-side, as in the money-wort, *Lysimachia Nummularia*, and periwinkle, *Vinca minor*, floating as in many water-plants, *climbing* (*scandent*), as in the ivy, or *twining*, when it may twine either to the right,[1] as in the hop or honeysuckle, or more often to the left, as in the bindweed (Figs. 113, 114).

The base of the stem or underground stem is distinguished from the true root by its power of producing leaves. These are, however, often dry or deciduous, and their presence can then only be recognised by the scars they leave behind; and sometimes they disappear so early that even the scars can scarcely be made out. In such cases the earliest stages of development must be examined in order to come to a determination. The underground stem assumes peculiar forms in the rhizome, tuber, and bulb.

The *rhizome* (Fig. 108, p. 77) is found in many perennial plants. It may be recognised by the leaf-scars, as also by its putting out a number of adventitious roots from its under side, and ascending annual branches (shoots) into the air from its extremity or from the neighbourhood of the leaf-scars. The buds of these shoots hibernate beneath the ground (Fig. 115). Rhizomes are commonly branched, and not unfrequently elongated, and creep for a distance beneath the surface, as for example in couch-grass, *Triticum repens*; but are sometimes short and compressed, as in the *Iris*, solid, or sometimes hollow and divided into chambers, as in the water-hemlock, *Cicuta virosa*.

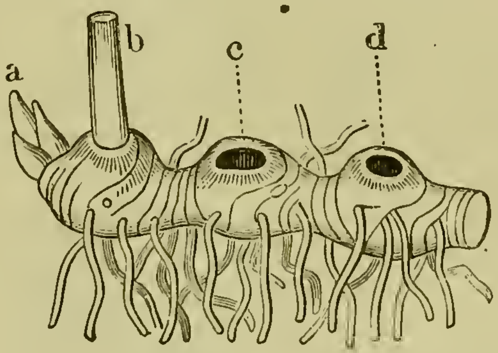

FIG. 115.—Rhizome of Solomon's seal, *Convallaria Polygonatum*. *a* terminal bud from which is developed the next year's stem; *b* this year's stem; *c*, *d*, scars of the stems of previous years.

The *tuber* is a thickened fleshy underground stem, with usually very small leaves which can be made out only in the young state; but in some cases, as the potato, there are a number of buds concealed in depressions, which are called *eyes* (Figs. 116, 117). Many plants form only one tuber, as the pig-nut, *Carum bulbocastanum* (Fig. 118), others several, as the potato. The spherical or palmate tubers of some orchids (Figs. 119, 120) are considered by some to be tuberous roots, by others true tubers.

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[1] [In applying the terms twining 'to the right' and 'to the left,' the reader must imagine himself in the position of the stem round which the climbing plant twines.—ED.]

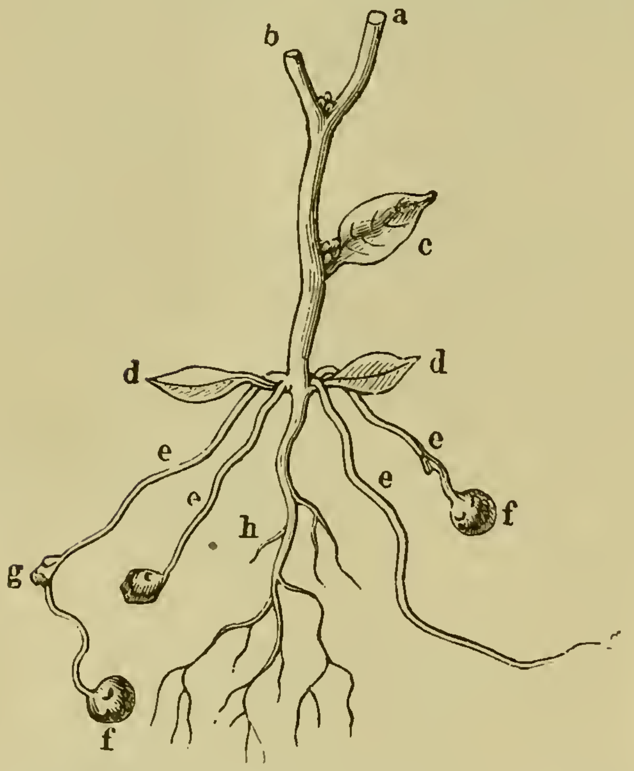

FIG. 116.—A six-weeks' old potato-plant developed from the seed, the upper branches *a b* being cut off; *d* cotyledons; in the axils of the cotyledons are developed the underground branches *c e*, which penetrate into the ground and form tubers *f g* at their apex or in the axils of small leaves. The tubers are formed only on the branches which are produced in the axils of the cotyledons, never on the true roots *h*.

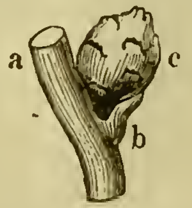

FIG. 117.—A tuber *c* formed in the axil between a small leaf *b* and the stem *a*. (× 2.)

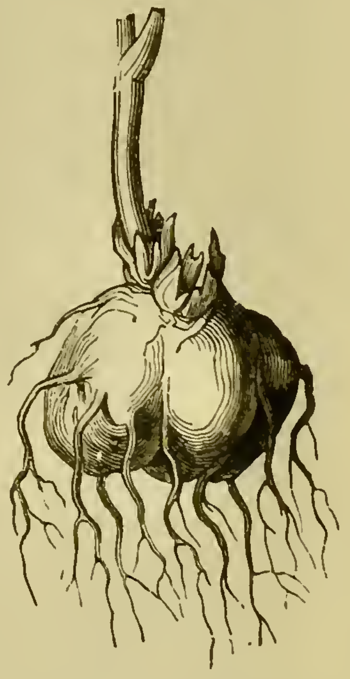

FIG. 118.—Single tuber of the pig-nut, *Carum bulbocastanum* (natural size).

The *bulb* is also fleshy, but is distinguished by its leaves, which [in the form of scales] surround the solid base of the stem which is called the *disc*, or are attached to its apex. This plate or disc is either comparatively large, and when surrounded by only a few leaves, as in the crocus, is called a *corm* (Fig. 121); or it may be comparatively small in proportion to the mass of the leaves, as in the onion [or hyacinth] (Fig. 122). Further characters are derived from the character of the scales; and bulbs are hence termed scaly

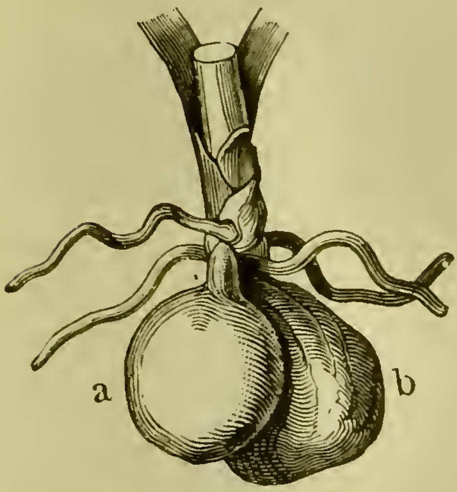

FIG. 119.—Double tuber, *a*, *b*, of *Orchis Morio*.

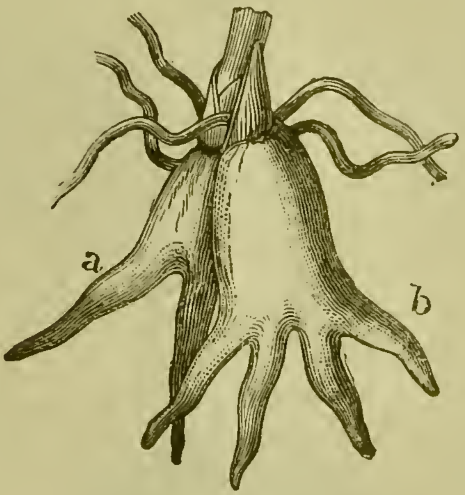

FIG. 120.—Double palmate tuber, *a*, *b*, of *Orchis odoratissima*.

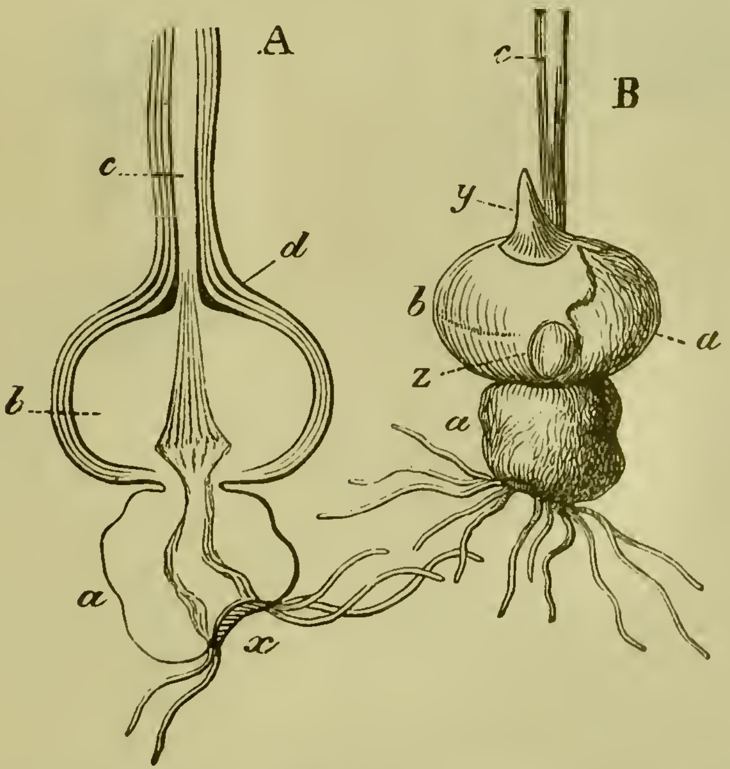

FIG. 121.—Corm of *Gladiolus segetum*; A longitudinal section; *a* last year's, *b* this year's bulb; *c* scape; *d* scales; *x* roots; B after removal of the enveloping scales; *y* bud which will develop into next year's bud; *z* bulbil.

or *squamose*, *tunicated* [in the hyacinth or onion], fibrous, &c.

THE BUD.

Branches of the stem spring, like leaves and flowers, from buds. According to the organs which result from their development, they are distinguished into stem-buds (*plumules*), *leaf-buds*, and *flower-buds*.

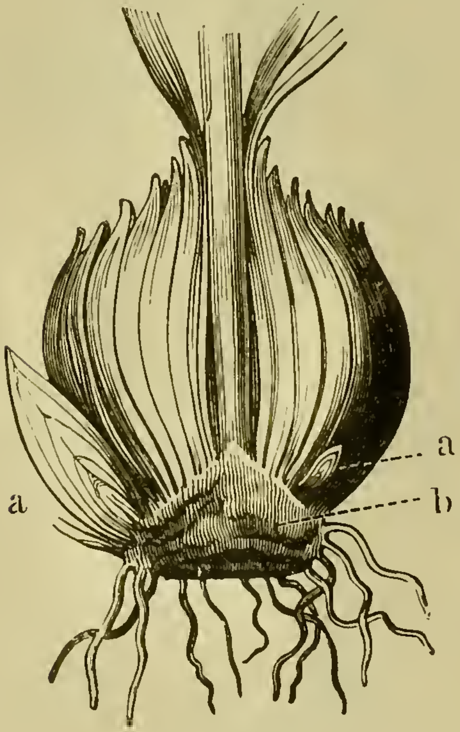

FIG. 122.—Scaly (squamose) bulb of the onion ; *b* plate or disc ; *a* bulbils.

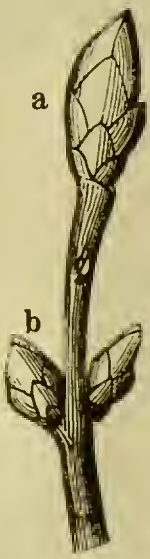

FIG. 123.—*a* Terminal bud ; *b* axillary bud, the leaf in the axil of which it was produced having been removed.

As respects the position of the bud, it is *terminal* (Fig. 123 *a*) when it is situated at the end of a branch, *axillary* (Fig. 123 *b*) when it grows in the axil of a leaf, *i.e.* in the angle which its upper surface makes with the stem, or *adventitious* when it springs from any other part of a stem except these two. The latter kind occur but rarely ; the tendrils of the grape-vine (Fig. 196, p. 108) proceed from buds of this description. In the same manner the shoots which spring from the creeping roots of certain plants, the plum, wild cherry, &c., originate from adventitious buds. There are sometimes a few buds which do not break through the bark, but remain dormant beneath it, until the other buds on the plant have been destroyed by unfavourable circumstances such as late frosts, when these *dormant* buds are excited into activity, and often preserve the life of the plant. But even while in the dormant state they always increase in size, and form, for example, the balls which are found beneath the bark of the beech, chestnut, lime, &c. Creeping stems are also sometimes developed from these, but more usually from adventitious buds. It is this production of branches on the stumps of felled trees, as on oaks and birches, which especially adapts them for growth as underwood. The bodies termed *bulbils* or *gemmæ* should also be mentioned here. They are stem-buds which detach themselves from the plant, and can themselves give rise to new individuals exactly like the parent. They are formed, for instance, in abundance on certain species of *Allium*, on the leaves of *Cardamine pratensis*, in the axils of the leaves of *Lilium bulbiferum*, between the scales of bulbs (Figs. 121, 122), [and more frequently with Cryptogams, on the fronds of 'viviparous' ferns, as *Asplenium bulbiferum*, normally on the thallus of Hepaticæ, &c.]

The mode of development of the buds has a great influence on the habit of the plant If, for example, the terminal bud of the primary stem persists as such, the stem will continue to grow for a long time at its apex, as may be seen in the silver fir. Pollarded willows, on the contrary, which have lost their terminal buds, usually form at their summit a dense crown of small branches. The dichotomous branching of the mistletoe depends on the terminal bud always developing into a flower, and the lateral buds into branches.

Buds which persist through the winter are usually protected by special organs, the *bud-scales*, which are either of a membranous or scaly texture. They are either dry as in the oak, viscid like those of the horse-chestnut, covered with hairs, or smooth. In many cases in which they are not specially developed, as in the lilac, they are replaced by ordinary leaves, or by some of special form which are considered as stipules, as in the alder. The bud-scales usually fall off when the bud begins to swell in the spring and the enclosed parts to grow : but in some cases, as the oak and beech, they continue to grow for some time at the base.

The stem-bud is a compressed rudiment of the stem, on which account the peculiar position of the organs which are attached to it can be especially well studied in the bud by making a transverse section through it.

The relative position of the bud-scales, foliage-leaves, sepals, and petals, in the bud, or, as it is termed, their *æstivation*, is usually *imbricate*, where the margins of contiguous leaves overlap one another, less often *valvate*, as in the calyx of the mallow (Fig. 124). where they merely touch one another by their edges. The most important modifications of the imbricate æstivation are the *enfolding* (Fig. 127) in which one leaf entirely encloses another, the *vexillary* (Fig. 128), peculiar to the Papilionaceæ, where one leaf much larger than the rest encloses the others ; *alternate*, as in the tulip (Fig. 129), where two rows of floral leaves alternate regularly with one another, and *quincuncial*, as in the wood-sorrel, the calyx of the rose, the calyx and corolla of the buttercup, &c. (Fig. 130), where the five leaves are so placed that between two outer ones which are entirely uncovered and two inner ones which are entirely covered, there lies a fifth (leaf 3), so inserted that with one of its margins it overlaps one of the two inner leaves, while the other margin is

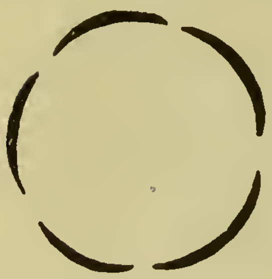
Fig. 124.— Valvate æstivation ; calyx of mallow.

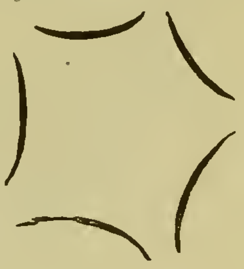
Fig. 125.—Reduplicate valvate æstivation.

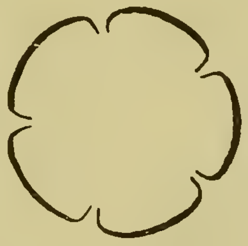
Fig. 126.—Induplicate valvate æstivation.

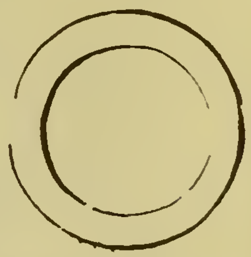
Fig. 127.—Enfolding æstivation.

covered by one of the outer leaves. If the whole bud appears as if twisted spirally, the æstivation is said to be *contorted;* if, as in the poppy, the leaves lie in the bud irregularly crumpled up, it is *crumpled.*

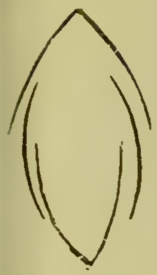

FIG. 128.—Vexillary æstivation of Papilionaceæ.

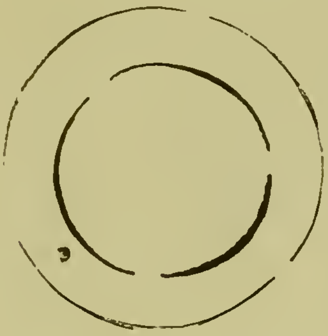

FIG. 129.—Alternate æstivation of tulip.

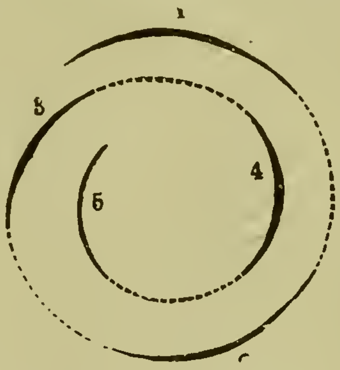

FIG. 130.—Quincuncial æstivation.

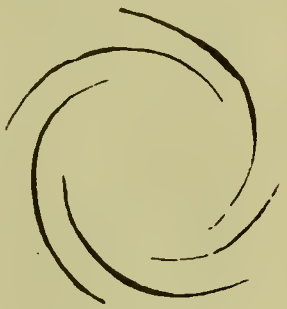

FIG. 131.—Contorted æstivation.

By *vernation* is meant the position occupied by the separate leaves in the bud. This is *flat* in the leaves of Coniferæ ; simply *folded* (Fig. 132) in those of the cherry and lime ; *plicate* or with many folds in those of the beech and birch Fig. 133). In their length from the apex to the base leaves

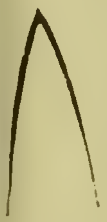

FIG. 132.—Simply folded vernation.

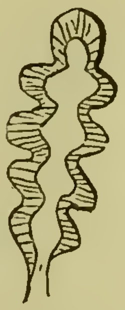

FIG. 133.—Plicate vernation.

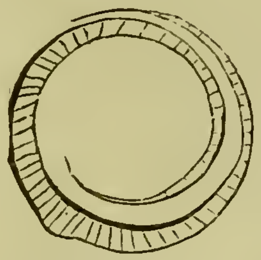

FIG. 134.—Convolute vernation.

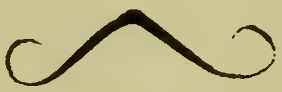

FIG. 135.—Revolute vernation.

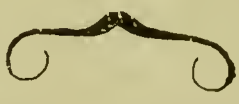

FIG. 136.—Involute vernation.

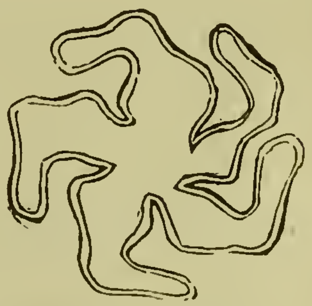

FIG. 137.—Contorted vernation.

are *circinate,* like the fronds of ferns, where the apex is rolled up towards the base ; *convolute* (Fig. 134), where one margin is rolled up towards the mid-rib, as in Grasses and bananas. The sepals of *Fumaria* are *revolute,* the margins being rolled outwards (Fig. 135) ; those of the sweet violet on the contrary are *involute* (Fig. 136), or rolled inwards towards the mid-rib. The petals of *Convolvulus* (Fig. 137) are *contorted* spirally; those of the poppy irregularly *crumpled*.

With respect to their anatomical structure, it may be remarked that buds are especially distinguished by the presence of formative tissues.

THE LEAVES.

It will be seen from what has now been said that the Leaves are appendicular organs of the stem. The apex is always formed first, and is therefore the oldest part of the leaf; the remaining parts being gradually interposed between it and the stem. The order of development is therefore the reverse in the leaf to what it is in the stem, where the apices are the youngest parts.

The various positions and functions of leaves necessitate their classification into four kinds:—*seed-leaves* or *cotyledons*, *covering-leaves*, *foliage-leaves*, and *floral leaves*. The first of these kinds will be more fully described when speaking of the seed; the last when speaking of the flower.

Covering-leaves are so called because they cover or protect other parts of the plant. In this class are included the *bud-scales* already described (p. 83), and the *bracts* or hypsophyllary leaves, *i.e.* those leaves in the axils of which the flowers are placed. The bud-scales are mostly brown bodies but little developed, which fall off as the development of the bud progresses, when they have fulfilled their purpose. The bracts are, on the contrary, as a rule more perfectly formed and green, or of some other colour as in the spathe of *Calla* [or *Richardia*, or the brilliant red bracts of *Poinsettia*, *Bougainvillea*, &c.] Their presence or absence, and their more or less complete development, are important in determining the nature of the inflorescence, and in defining the characters of certain families of plants. The *glumes* of Grasses, the *spathe* of Aroideæ, the *paleæ* of Compositæ, and the *involucre* of Umbelliferæ [and Compositæ], are different forms of bracts.

To this class belong also the *scale-* or cataphyllary *leaves*, which are either colourless, yellowish, reddish, brown, or rarely green; often fleshy, leathery, or membranous, and which for the most part remain buried in the ground. When the true foliage-leaves are strongly developed, the scale-leaves are generally inconspicuous; while in other plants they are conspicuous, as in saprophytes which are destitute of chlorophyll and have no true leaves (Fig. 346, p. 166).

The *foliage-leaves*—often called simply leaves—are distributed over the stem in a great variety of ways. When there is more than one on the same level they are *opposite*, *decussate* (Fig. 138), or *verticillate* (Fig. 139); when there is only one on the same level, *alternate* or *scattered* (see p. 76). Irregular as the arrangement appears in the last case, a close investigation nevertheless shows that these also are distributed on the stem in accordance with definite laws. If a spiral is drawn round the stem connecting the points of attachment of the leaves, and these are then marked on the spiral, it is found that in any particular species there is always a certain definite number of leaves on any given number of circuits made by the spiral round the stem. The course of the spiral from any one leaf to the next leaf which stands exactly vertically above or beneath it is therefore termed the *leaf-cycle*. In order to determine the law of *phyllotaxis* or leaf-arrangement in any particular species, the number of leaves in a cycle is placed as the denominator of a fraction, and the number of circuits round the stem included in the cycle as the numerator. Thus, for example, the leaves of the pear, oak (Fig. 140), poplar, and walnut, have a $\frac{2}{5}$ arrangement; *i.e.* five leaves are found on every two circuits which make up the cycle. In *Plantago* (Fig. 141) the phyllotaxis is $\frac{3}{8}$. That the law of phyllotaxis, to which the floral leaves are also subject, must have a great influence on the æstivation is self-evident: thus the quincuncial æstivation corresponds to the $\frac{2}{5}$ phyllotaxis. The spiral itself may either be a right-handed one, *i.e.* running from the left below to the right above, or conversely a left-handed one. The law thus indicated is not, however, always easy to recognize in practice. Of the leaves of Grasses, for example, one half follow a right-handed, the other half a left-handed spiral. The spiral arrangement is often obscured by the leaves standing in a fasciculate

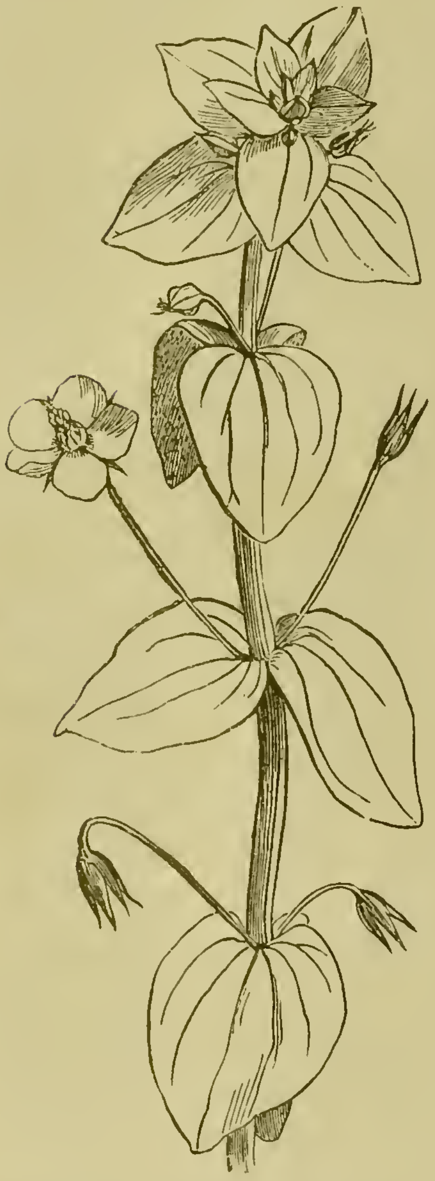

FIG. 138.—Decussate leaves of the scarlet pimpernel, *Anagallis arvensis*, with axillary flowers.

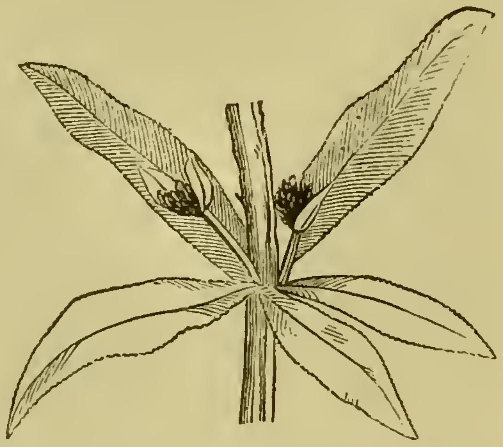

FIG. 139.—Verticillate leaves of the madder, *Rubia tinctorum.*

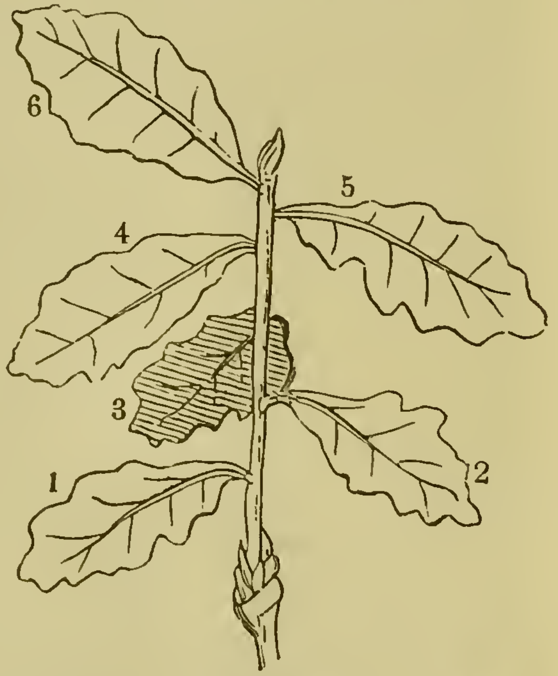

FIG. 140.—2/5 phyllotaxis of the oak.

manner on a branch which has remained undeveloped, as in the larch.

Since the secondary axes (branches) generally spring from axillary buds, it follows that their arrangement on the stem is dependent on the phyllotaxis of those leaves in the axils of which they arise, as is seen at once in any labiate plant. It is also easily understood that an apparently altogether irregular arrangement of the branches on the stem may be the result of the abortion of a number of buds.

A leaf of the most perfect development may be divided into its sheath, its petiole or leaf-stalk, and its lamina or flatly expanded blade, although one or other of these parts is most often wanting. Thus the leaves of Grasses have a sheath, but no petiole ; those of the apple and pear a petiole, but no sheath ; in those of many Umbelliferæ, such as *Angelica*, all three parts occur.

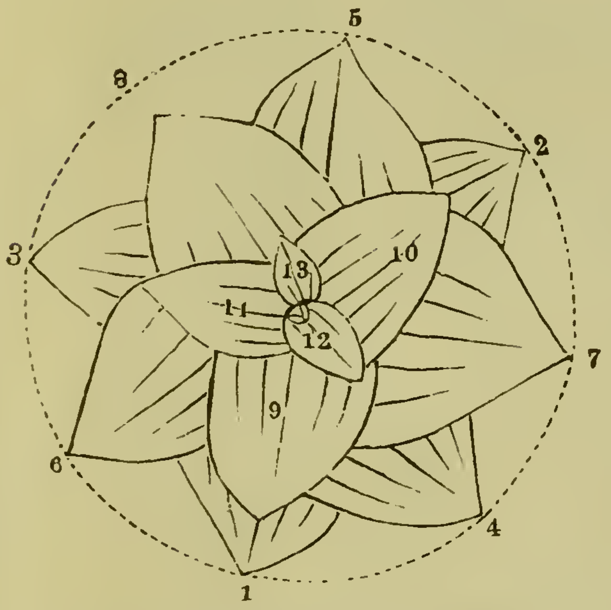

FIG. 141.—Diagram of the 3/8 phyllotaxis of *Plantago*.

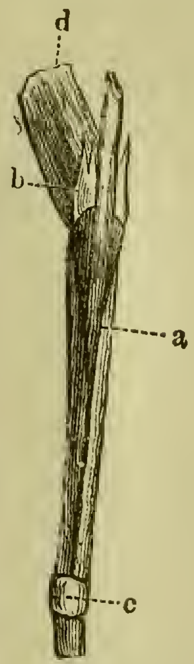

FIG. 142.—*a* Split leaf-sheath of a grass ; *b* ligule ; *d* part of the lamina of the leaf ; *c* node of the culm.

The *leaf-sheath* embraces the stem in the form of a hollow tube. In Grasses it is always split in front (Fig. 142) ;

in rushes and sedges, on the contrary, closed or entire. The split sheath of many Umbelliferæ is inflated; while the closed sheath of the knot-grass, *Polygonum*, does not bear the leaf at its upper end, but on its back, and is in this case called an *ochrea.*

The *petiole* is not always present; and leaves are hence distinguished into *petiolate* or stalked, and *sessile.* It is often connected with the stem, rarely with the sheath, by a peculiar more or less swollen articulation. If this articulation is large, and a portion of it remains attached to the stem after the fall of the leaf, as in the spruce-fir, the portion that thus remains is called a *pulvinus.* After the fall of the leaf, the spot to which it was attached is indicated by a scar or cicatrix. The petiole may be cylindrical, semicylindrical, channeled, or flat, and is sometimes winged, or provided

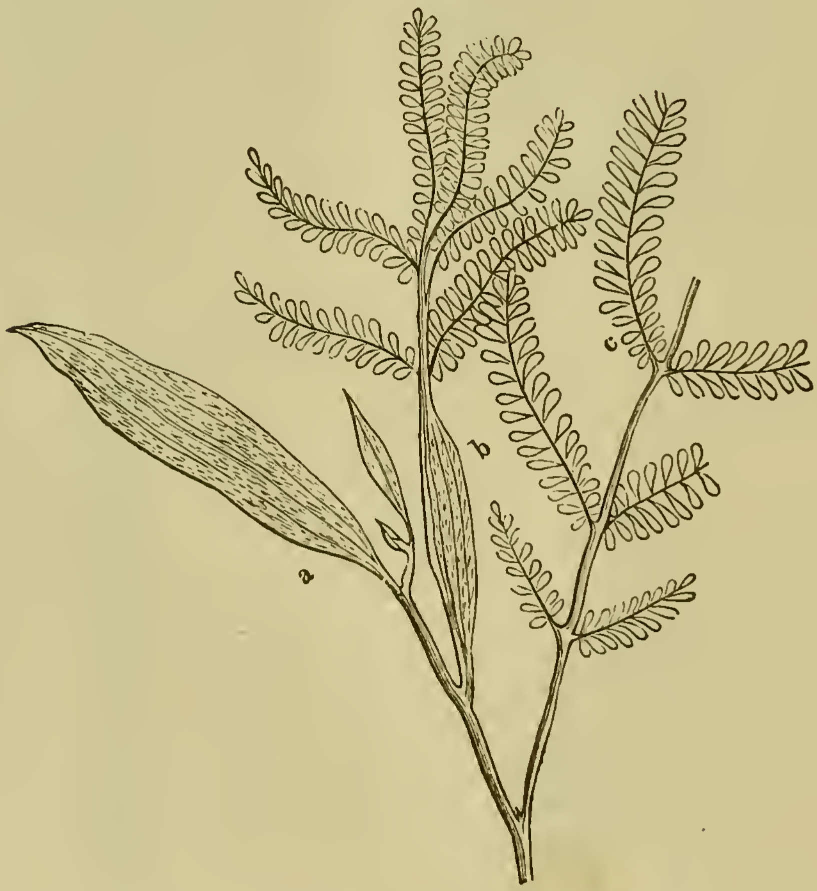

Fig. 143.—Branch of *Acacia melanoxylon,* showing phyllodes, *a b.*

with leaf-like expansions at the side. Some Australian species of *Acacia* possess in the early years of their life bipinnate leaves with a more or less flatly expanded petiole (Fig. 143, *b*); but subsequently the pinnæ are no longer developed, the branching is also suppressed, and the simple petiole, now strongly developed into a flat plate (Fig. 143, *a*), performs all the functions of the leaf. Such a petiole is termed a *phyllode*, and is distinguished from leaves of normal structure by its mode of development, as well as by its vertical position.[1]

At the base of the petiole on both sides are frequently found flat leaf-like appendages, the *stipules* (Figs. 144, 145).

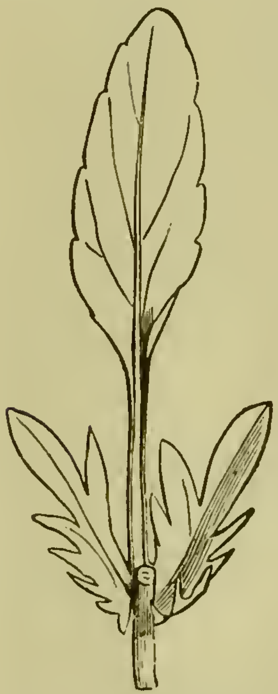

Fig. 144.—Leaf of the pansy, with two large stipules.

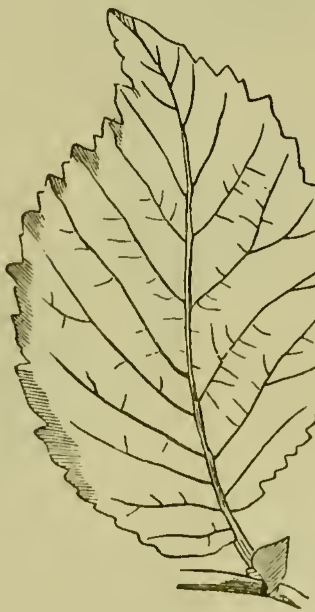

Fig. 145.—Leaf of the elm, with small stipules.

These are sometimes adherent to the petiole, or *adnate*, as in the rose, and occasionally even run down a portion of the stem itself as in the wood-vetch, *Vicia sepium*, when they are *decurrent*, and give a winged appearance, either to the petiole or to the stem. [When not adherent to the petiole they are said to be *free* (Fig 154, p. 95).] The stipules are mostly smaller than the true leaves, seldom larger, as in the pansy (Fig. 144). In *Lathyrus Aphaca* (Fig. 146), the stipules of the upper leaves are the only part to expand, the leaf itself degenerating into a tendril. The stipules of *Gleditschia* and the common 'acacia,' *Robinia pseudacacia* (Fig. 184, p. 103), are spinous; they are leaf-like and persistent in the pea, membranous and deciduous in the oak and beech.[1] Under the head of stipules come the *ligules* (Figs. 142, 147), or delicate appendages which grow at the point of union of lamina and sheath in the leaves of Grasses.

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[1] [The petiole of *Sarracenia* and *Darlingtonia* is expanded into a remarkable pitcher-like organ capable of holding a considerable amount of fluid. The somewhat similar pitchers of the 'pitcher-plant' or *Nepenthes* (Fig. 193, p. 106) are considered on the other hand to be expansions of the lamina.—Ed.]

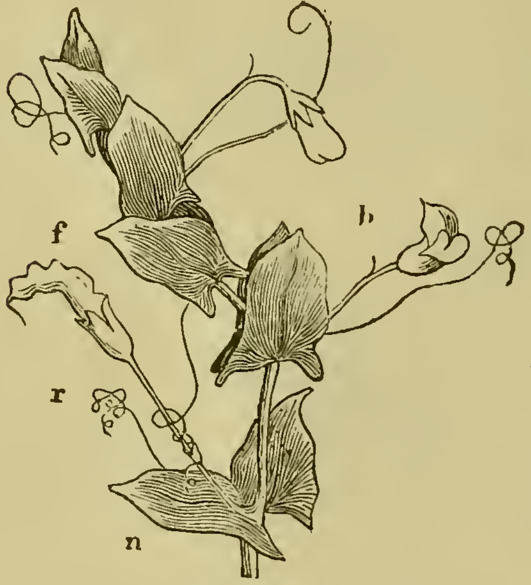

FIG. 146.—*Lathyrus Aphaca*; *r* tendril; *b* flower; *f* fruit; *n* stipule.

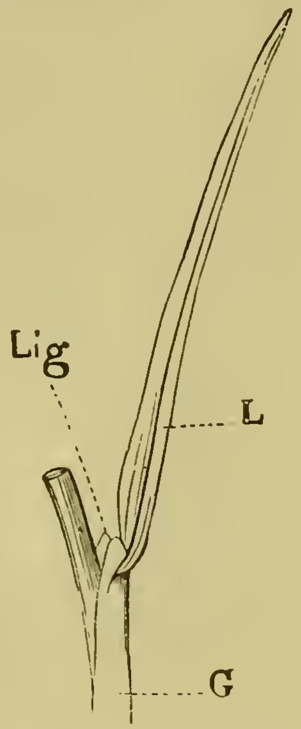

FIG. 147.—Leaf of grass; *Lig.* ligule; L lamina; G leaf-sheath.

Sessile leaves sometimes partly or entirely embrace the stem, and are then *amplexicaul*, or semi-amplexicaul. In the former case the base is occasionally developed in a sheath-like form, sometimes not, as in the common buttercup (Fig. 148). So-called *perfoliate* leaves, as in *Bupleurum rotundifolium* (Fig. 149), or *connate* leaves, as in the common honeysuckle (Fig. 150) [or *Chlora perfoliata*], are varieties of the amplexicaul

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[1] [In pinnate leaves, each of the petiolules or separate petioles of the leaflets is sometimes furnished at its base with a secondary stipule or *stipella*.—ED.]

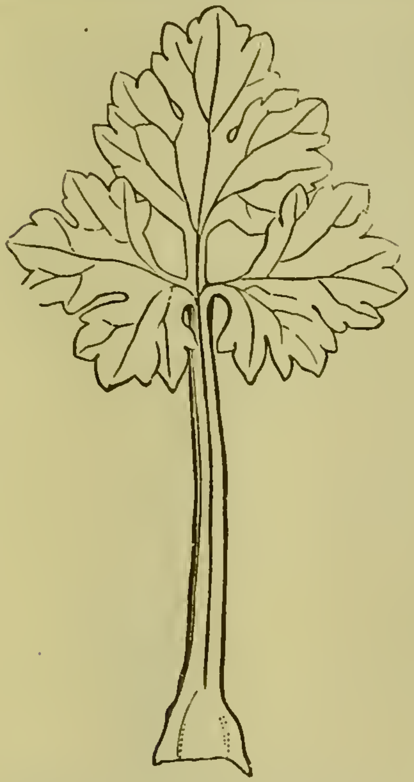

FIG. 148.—Amplexicaul leaf of the buttercup, with petiole expanded at the base.

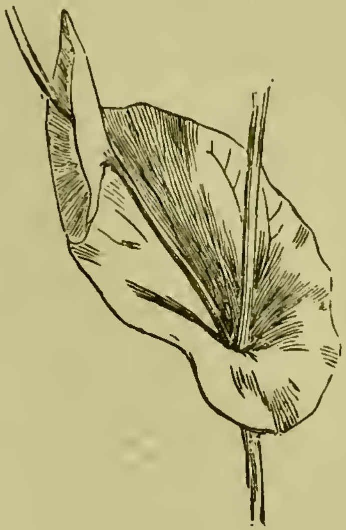

FIG. 149.—Perfoliate leaf of *Bupleurum rotundifolium.*

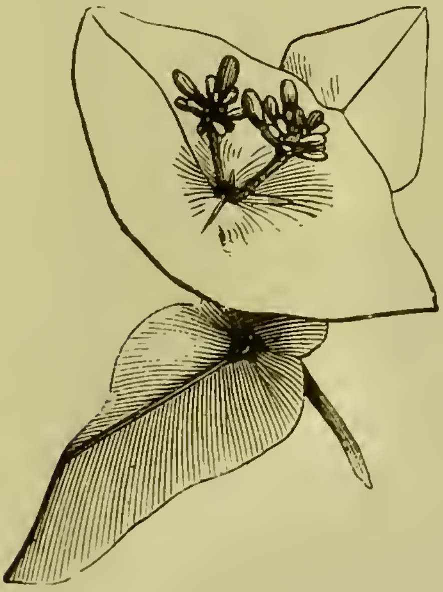

FIG. 150.—Connate leaves of the honeysuckle.

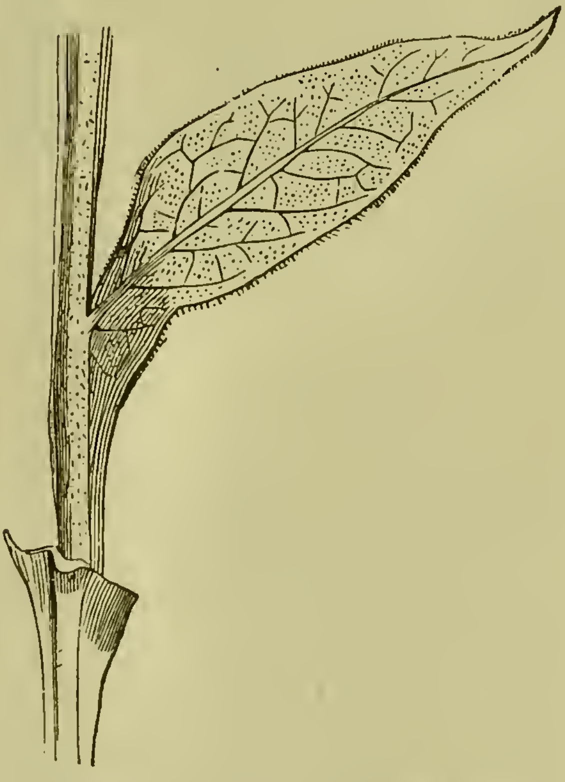

FIG. 151.—Decurrent leaf of *Symphytum officinale*, the stem hence becoming winged on one side.

form. In the former case the two margins of the base of the leaf have united; while the latter variety consists of two leaves which have become completely united at the base in their growth. Not unfrequently the leaf is united for a certain length with the stem, when it is said to be *decurrent* [and the stem to be *winged*], (Figs. 151, 152).

The *lamina* or blade, the most essential part of the leaf, may assume almost any conceivable form. The first thing to observe is whether the petiole bears only a single lamina, or several, connected with it by secondary petioles or *petiolules*, or by articulations. In the first case the leaf is said to be *simple*, in the latter cases *compound*.

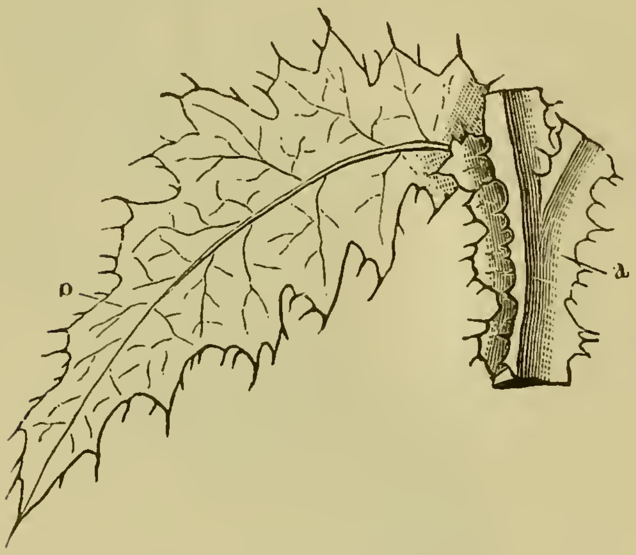

FIG. 152.—Decurrent spiny leaves of thistle, the stem *a* hence becoming winged.

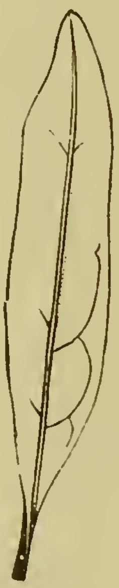

FIG. 153.—Lanceolate leaf of the privet.

The separate leaflets of a compound leaf, as well as the single lamina of a simple one, may have the greatest variety of external form. *Linear* leaves are such as are not only many times longer than broad, but are of nearly the same width from the base to near the apex, as in nearly all Grasses. If the leaves are at the same time somewhat rigid, as in *Iris*, they are *ensiform*; and if they are also sharp-pointed like those of most Coniferæ, they are *acicular* or *acerose*. A *lanceolate* leaf (Fig. 153) is three or four times as long as broad, and is narrowed to a point both at the base and the apex. In the *elliptical* or *oval* (Fig. 154), and the *oblong* leaf, the ends are equally rounded off; the former is two to three, the latter three to four times as long as broad. The terms *ovate* (Fig. 168, p. 98) [where the broadest part is nearer the base than the apex], *obovate*, [where the broadest part is nearer the apex than the base], *sub-rotund*, *orbicular* (Fig. 155), *cordate* (Fig. 156), *obcordate* (Fig. 157), *triangular*, as in

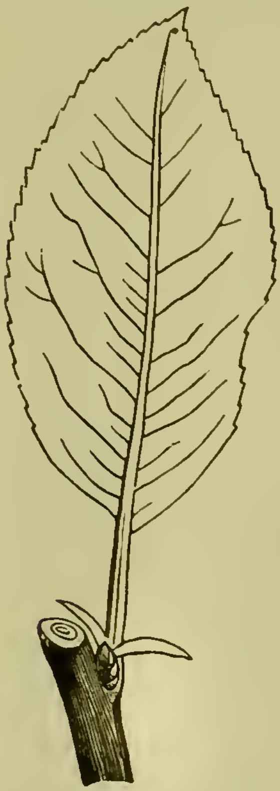

FIG. 154.—Oval leaf of the apple [with two free stipules].

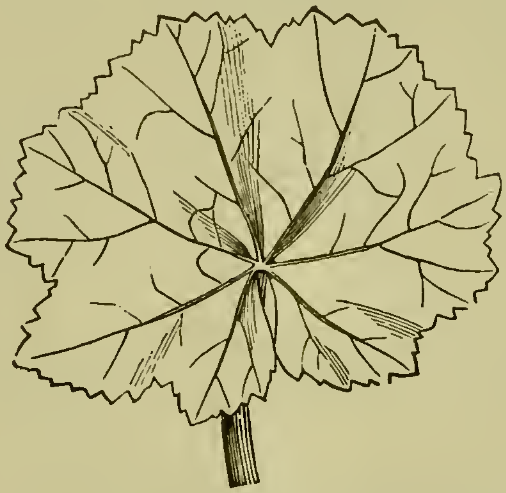

FIG. 155.—Orbicular leaf of *Malva rotundifolia*.

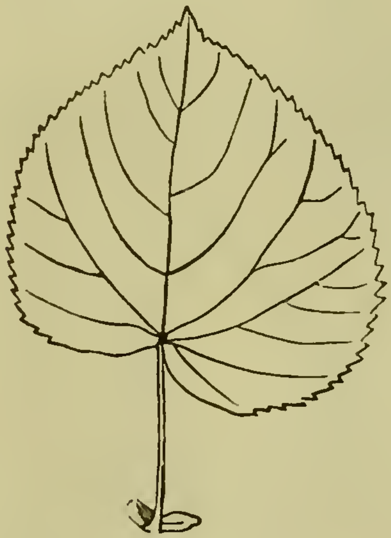

FIG. 156.—Cordate [unsymmetrical] leaf of the lime.

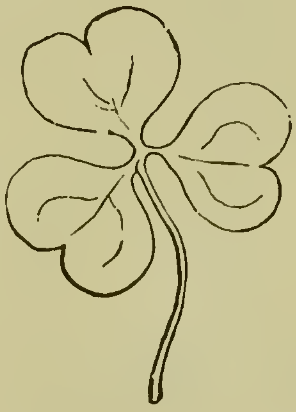

FIG. 157.—Leaf of *Oxalis micrantha*, with three obcordate leaflets.

Atriplex patula (Fig. 158), and *rhomboidal*, are used in their obvious signification. A *reniform* leaf (Fig. 159) is one that is broader than long, and has the apex rounded off, with two projecting lobes at the base also rounded off. *Sagittate* (Fig. 160) and *hastate* (Fig. 161) leaves are pointed at the apex, and have also two pointed lobes at the base ; the incision bounded by these latter is acute-angled

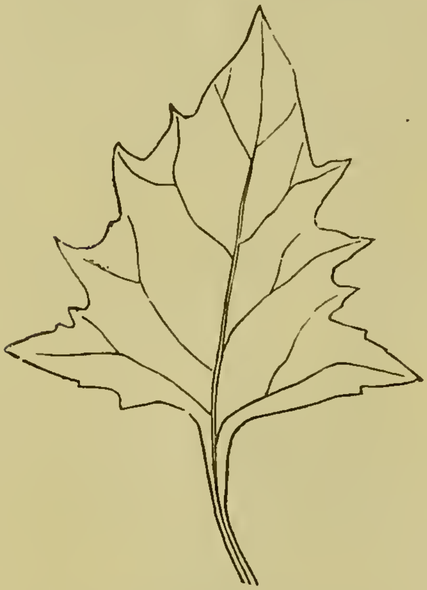

FIG. 158.—Triangular leaf of *Atriplex patula.*

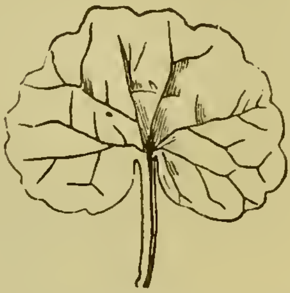

FIG. 159.—Reniform leaf of the ground-ivy, *Nepeta Glechoma.*

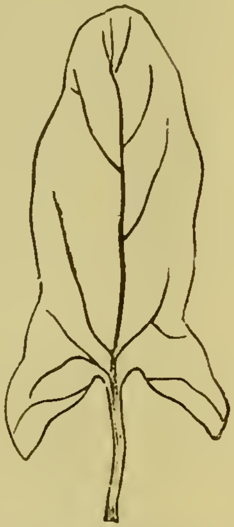

FIG. 160.—Sagittate leaf of *Convolvulus arvensis.*

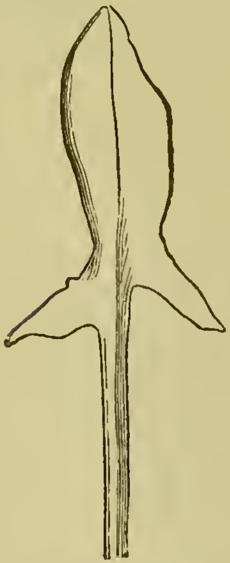

FIG. 161.—Hastate leaf of *Rumex acetosa.*

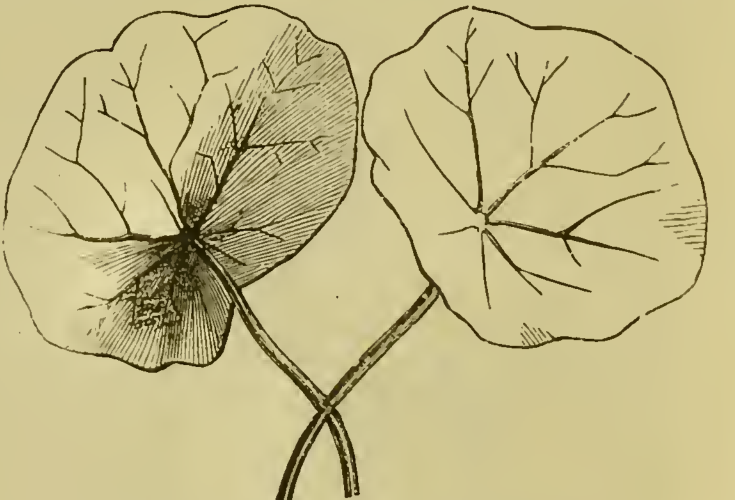

FIG. 162.—Peltate leaf of *Tropæolum.*

in the former, very obtuse-angled in the latter case. In the *peltate* leaf (Fig. 162), the petiole springs from the middle of the lamina [as in *Hydrocotyle* or *Tropæolum*].

In describing the form of the base of the leaf, *i.e.* of the part of it which is attached to the stem or petiole, some of the same terms are applicable as those already defined; as, for example, cordate, reniform, hastate, &c. There are some others also in use. Thus the base may be *cuneate* or wedge-shaped (Fig. 163), when it passes gradually into the petiole; and the *spathulate* leaf (Fig. 165) is somewhat similar [as in the London pride, *Saxifraga umbrosa*]. The apex of the leaf also often requires special description. It is *obtuse*, *acute*, *acuminate* [when the apex narrows rapidly and lengthens into a point] (Fig. 164), *mucronate* (Fig. 166) [when ending abruptly in a short sharp point,] *truncate* [as in the tulip-tree, *Liriodendron*], *emarginate* (Fig. 167) [when indented at the apex], or *obcordate* (Fig. 157, p. 95).

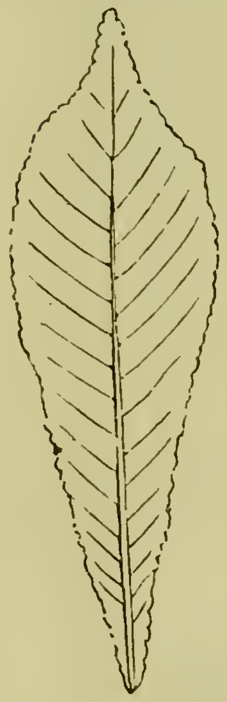

Fig. 163. — Cuneate leaflet from the leaf of the horse-chestnut.

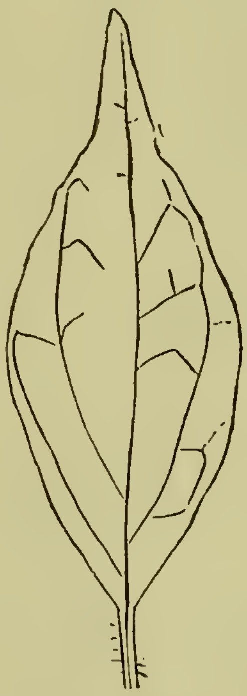

Fig. 164.—Acuminate leaf of the pellitory, *Parietaria*.

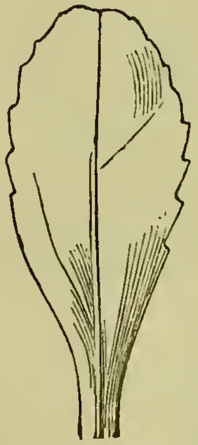

Fig. 165. — Spathulate leaf of the ox-eye daisy, *Chrysanthemum leucanthemum*.

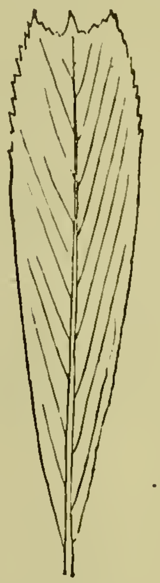

Fig. 166 —Mucronate leaflet of the lucern (magnified).

In but comparatively few cases is the lamina entirely without incisions of any kind. In the great majority there are either smaller notches which affect only the margin, or deeper incisions which cause the leaf to assume a different form, or both may occur on the same leaf. In reference to the margin, the leaf may be *entire* [without notches of any kind, as in all Grasses, Caryophyllaceæ, *Vinca*, &c.]; *dentate* (Fig. 168) [when the teeth are sharp and point outwards with concave edges], *serrate* (Fig. 169) [when the teeth are

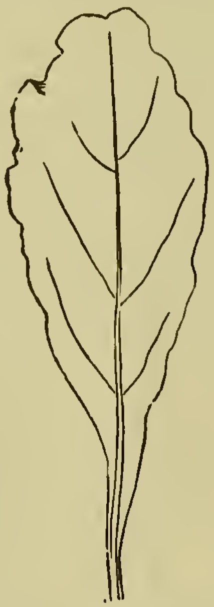
Fig. 167. — Emarginate leaf of *Amaranthus*.

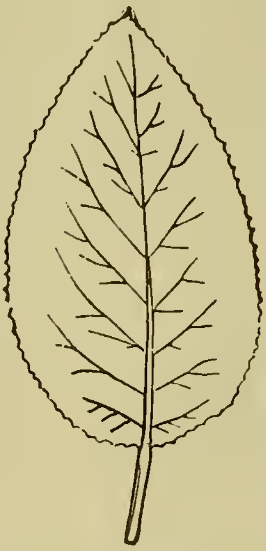
Fig. 168.—Dentate ovate leaf of the guelder-rose, *Viburnum Opulus*.

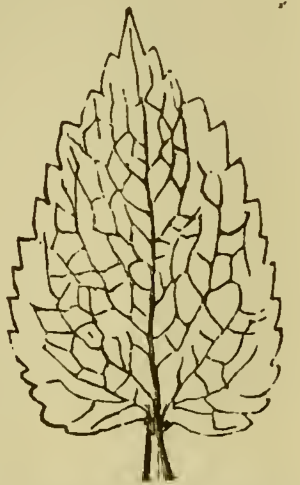
Fig. 169.—Serrate leaf of *Lamium*.

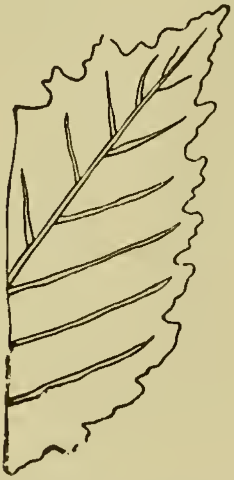
Fig. 170.—Part of the bi-serrate leaf of the elm.

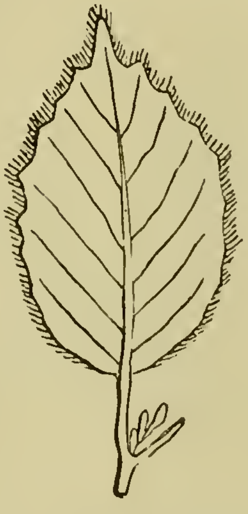
Fig. 171.—Ciliate leaf of the beech.

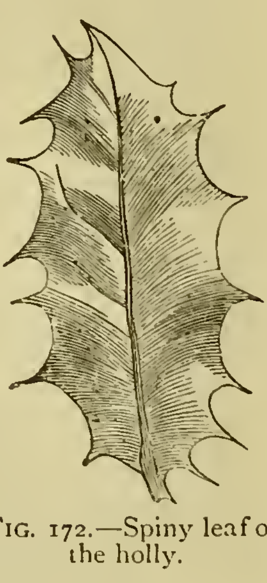
Fig. 172.—Spiny leaf of the holly.

sharp and point forwards towards the apex like the teeth of a saw]; *biserrate* (Fig. 170); *crenate* (Fig. 159) [when the teeth are rounded off with convex edges]; or *repand* [when the margin is wavy]. A leaf is *ciliate* (Fig. 171) [when fringed with hairs on the margin], *spiny* (Fig. 172) [when the teeth are long and very sharp], rough or *scabrous* when provided with small scarcely visible roughnesses.

If the margin of a leaf or leaflet is more deeply cut than is indicated by the terms just mentioned, it is *incised*, and *pinnatisect* if the divisions extend [very nearly] to the mid-rib (Fig. 174); *palmatisect* if they extend [very nearly] to the base of the leaf (Fig. 173); *pinnatipartite* and *palmatipartite* (Fig. 183, p. 102) respectively if the incisions do not extend quite so far; and *pinnatifid* and *palmatifid* when they extend about half-way from the margin to the mid-rib or base of the leaf. If the divisions of a palmatifid leaf are five in number, it is called *palmate* (Fig. 181, p. 102). Special modifications of the pinnatifid leaf are the *runcinate* (Fig. 175), where the points of the large central lobes are reflexed; *lyrate* (Fig. 176), where the terminal lobe is much the largest, and the others decrease

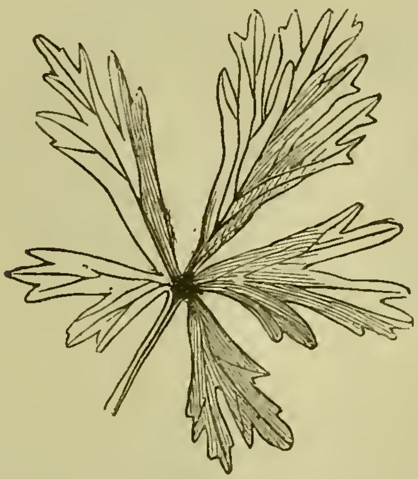

FIG. 173.—Palmatisect leaf of the monks-hood, *Aconitum*.

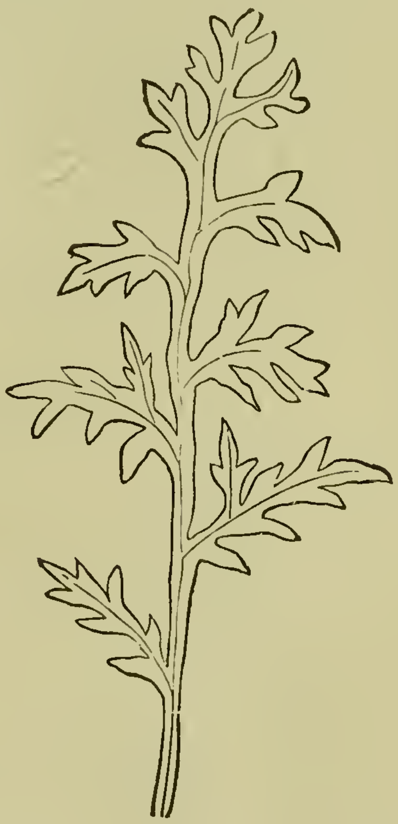

FIG. 174.—Pinnatisect leaf of the common poppy, *Papaver Rhœas*.

gradually towards the base; *laciniate* (Fig. 177), where the leaf is irregularly cut into very narrow segments. In a *slit* leaf the lobes into which the margin is divided are narrow and pointed; in a *lobed* leaf (Fig. 179) they are broader and rounder (with the exception often of the terminal lobe), the incisions themselves having an acute angle; in a *sinuate* leaf (Fig. 180) still broader and shallower, the incisions themselves being also rounded off. According to the number of the divisions, the leaf is *trifid*, *trilobed* (Fig. 179), *five-lobed*, &c., or the latter is usually called *palmatilobed*.

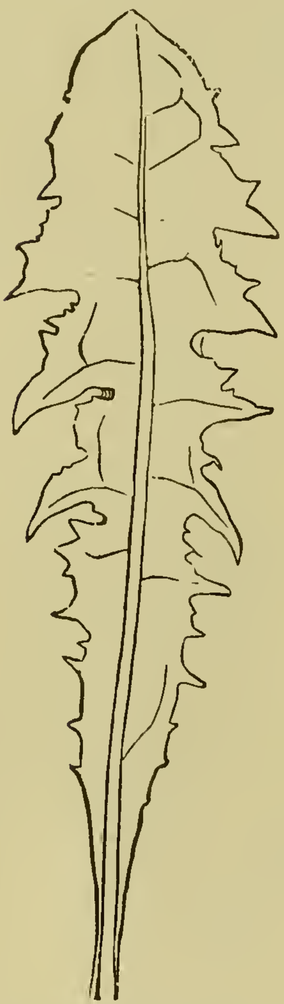

FIG 175.—Runcinate leaf of the dandelion.

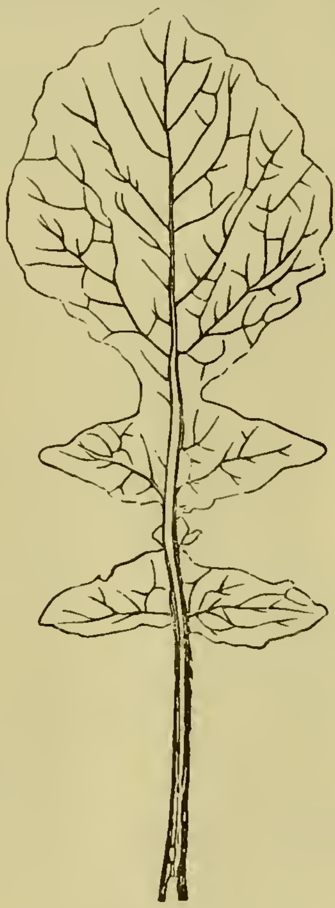

FIG. 176.—Lyrate leaf of the white mustard, *Brassica alba*.

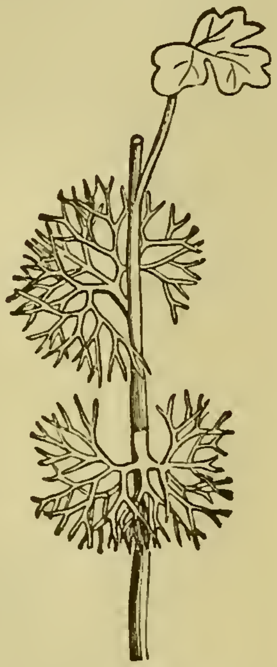

FIG. 177. — Heteromorphic leaves of the water crowfoot, *Ranunculus aquatilis*: the floating leaves trilobed, the submerged leaves laciniate.

Compound leaves are classed under two principal heads, the *digitate* and the *pinnate*. In the former, several leaflets —3, 5, 7, or less often 4— spring from the apex of the common petiole. The most common number is 3, as in the clover (Fig. 182, p. 102), when the leaf is said to be *ternate* or *trifoliolate*. When the petiole divides at its apex into two main divisions, each of which bears several leaflets, it is *pedate* (Fig. 183). The pinnate leaf has its leaflets arranged on each side of a common elongated petiole, which is then called the *rachis.* If the rachis ends in a terminal leaflet [so that the number of the pinnæ is uneven] the leaf is unequally pinnate or *imparipinnate* (Fig. 184); if the number of leaflets is an even number it is *paripinnate* or equally pinnate (Fig. 185); and in this case the rachis may run into a tendril or a point (Fig. 185), or may end abruptly. The leaflets may be opposite to one another on the rachis (Fig. 184), when each pair forms a '*jugum,*' or they may be alternate (Fig.

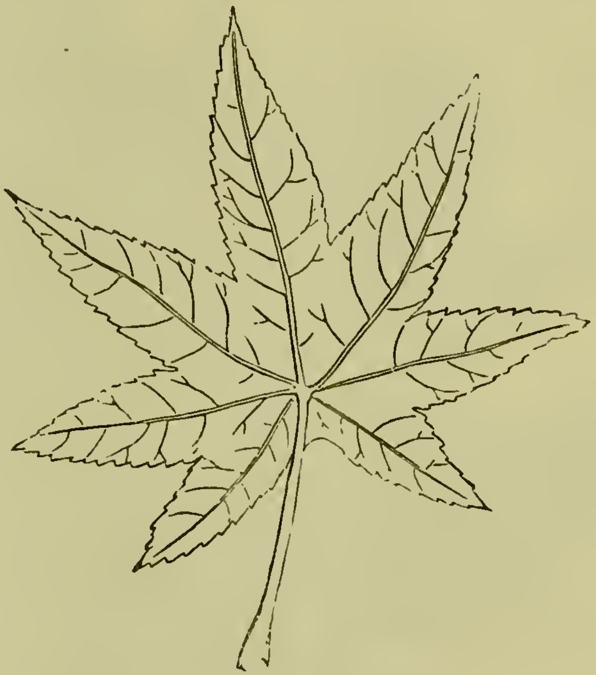

FIG. 178.—Palmatifid leaf of the castor-oil plant, *Ricinus communis.*

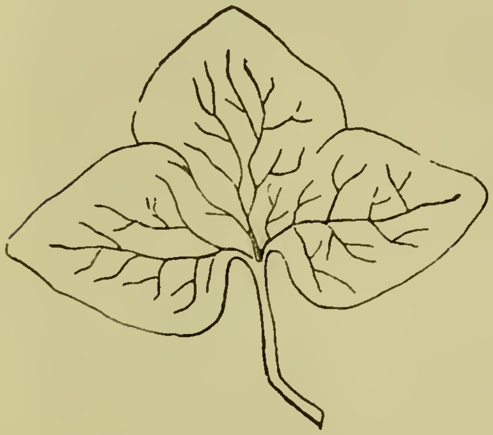

FIG. 179.—Trilobed leaf of the hepatica.

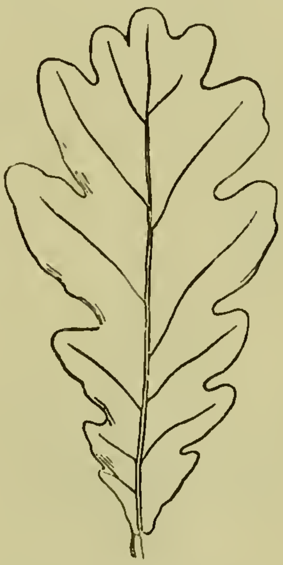

FIG. 180.—Sinuate leaf of the oak.

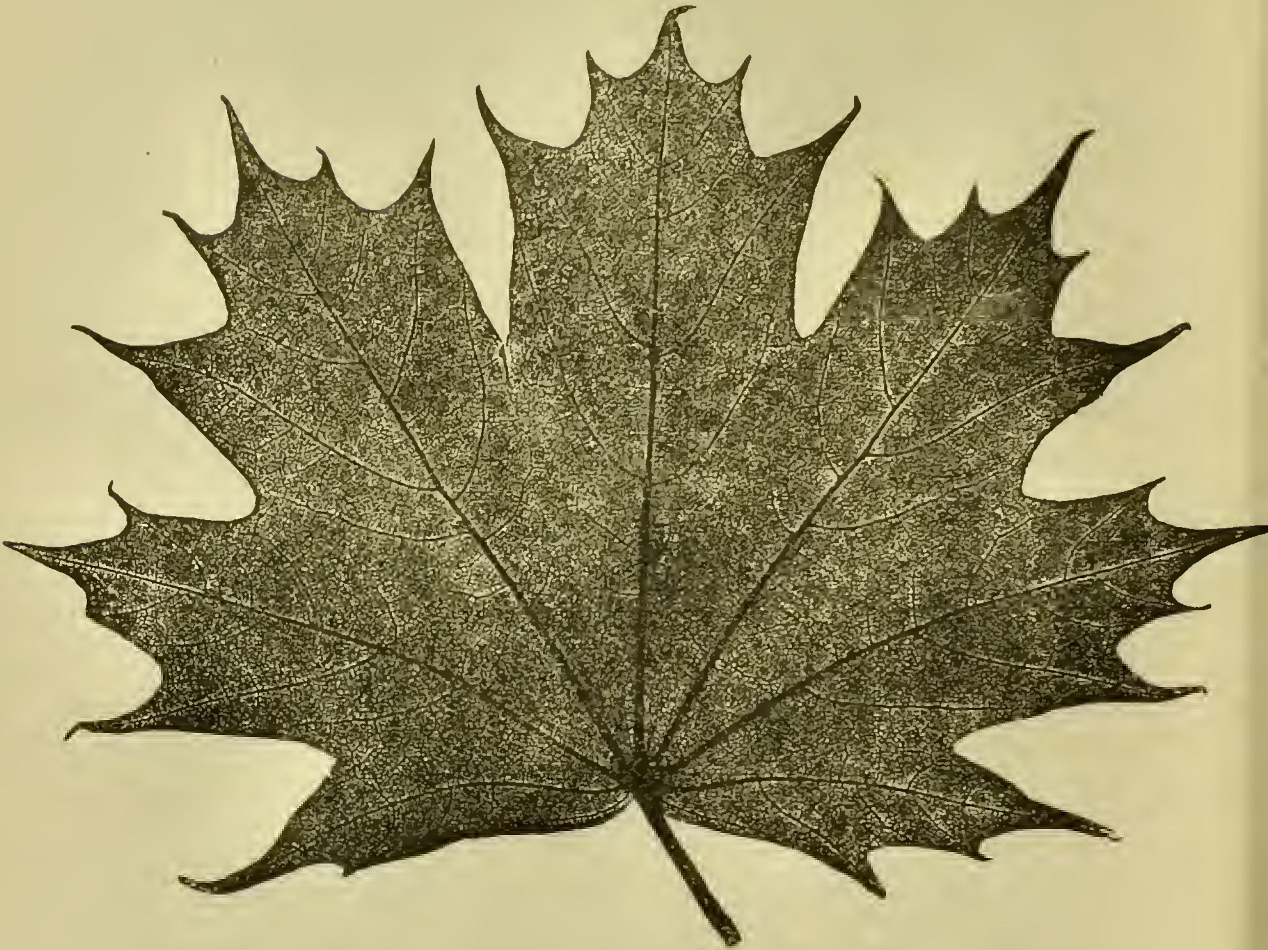

FIG. 181.—Palmate leaf of *Acer acutifolium* (nature-printed).

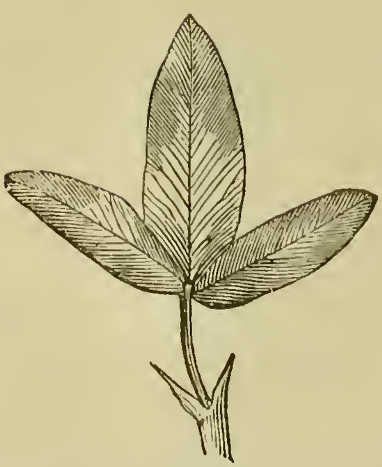

FIG. 182.—Trifoliolate leaf of the clover [with adnate stipules].

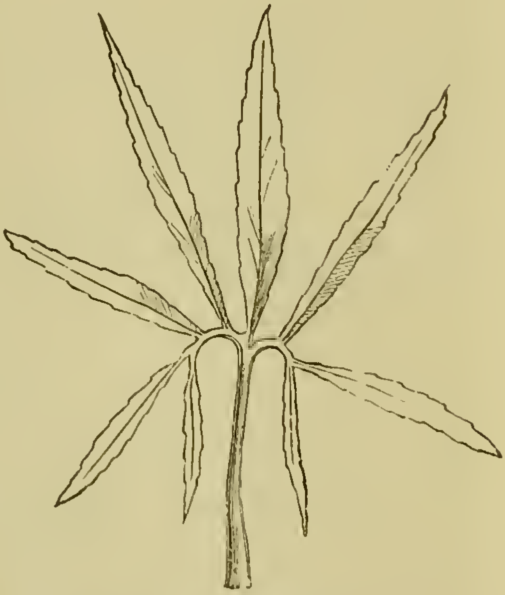

FIG. 183.—Pedate leaf of *Helleborus.*

185). If large and small leaflets alternate with one another, the leaf is *interruptedly pinnate* (Figs. 186, 187).

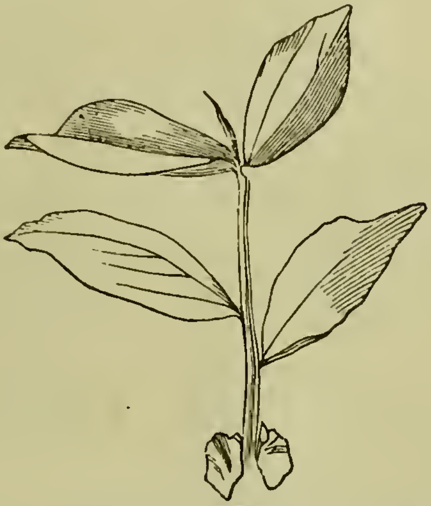

FIG. 185.—Paripinnate leaf of *Lathyrus macrorhizus* [with auriculate or ear-shaped stipules] the rachis ending in a point.

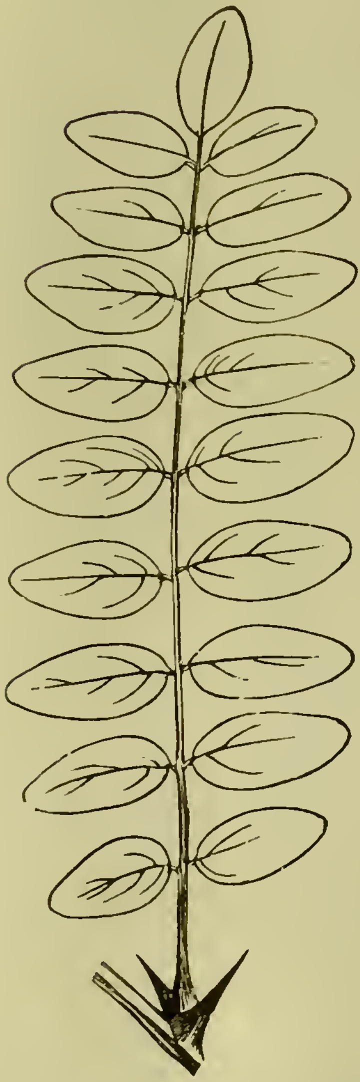

FIG. 184.—Imparipinnate leaf of the 'acacia,' *Robinia Pseudacacia.* with opposite leaflets [and spinous stipules].

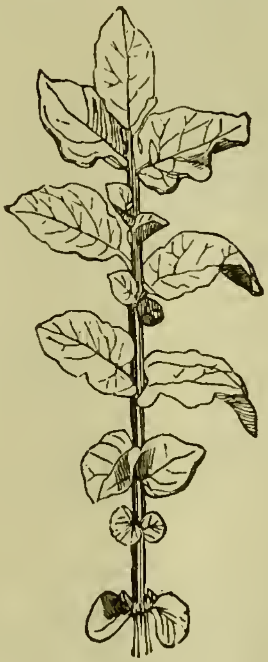

FIG. 186.—Interruptedly pinnate leaf of the potato.

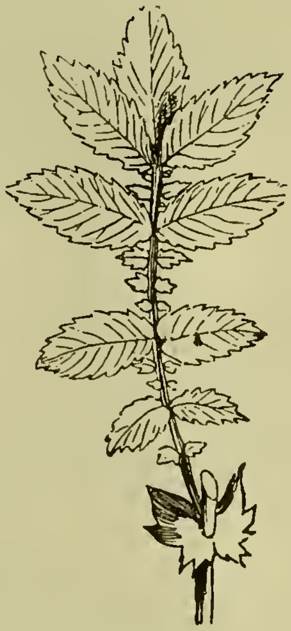

FIG. 187.—Interruptedly pinnate leaf of *Agrimonia Eupatoria* [with connate stipules].

In some cases the division into leaflets is repeated, and the leaf is then *supradecompound.* Thus we may have a *biternate* leaf (Fig. 188), [in which each of the trifoliolate sections is again trifoliolate], a *bipinnate* (Fig. 190), and even a *ter-* to *quinque-pinnate* leaf (Fig. 189). In the bipinnate leaf, which is of very common occurrence, the leaflets which are

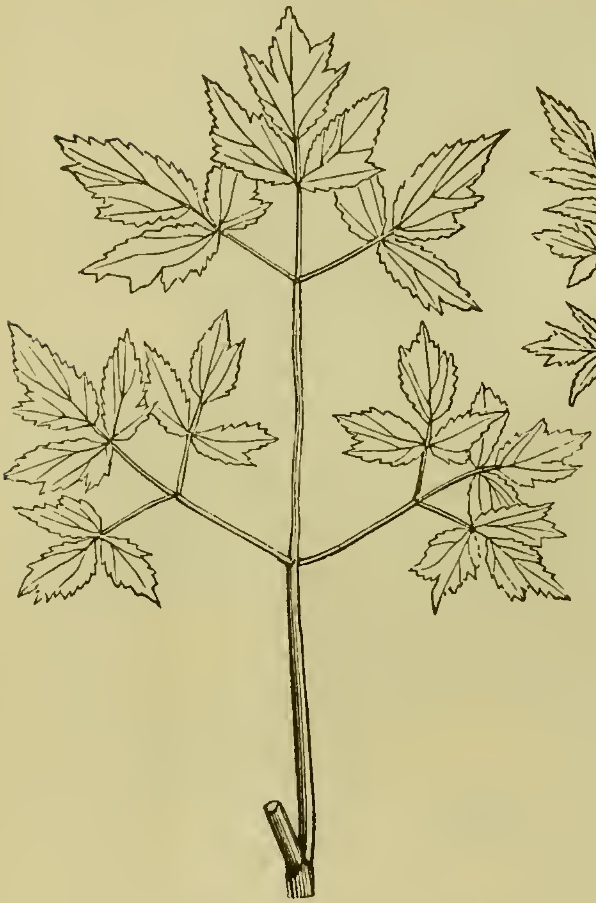

FIG. 188.—Biternate leaf of *Actæa spicata.*

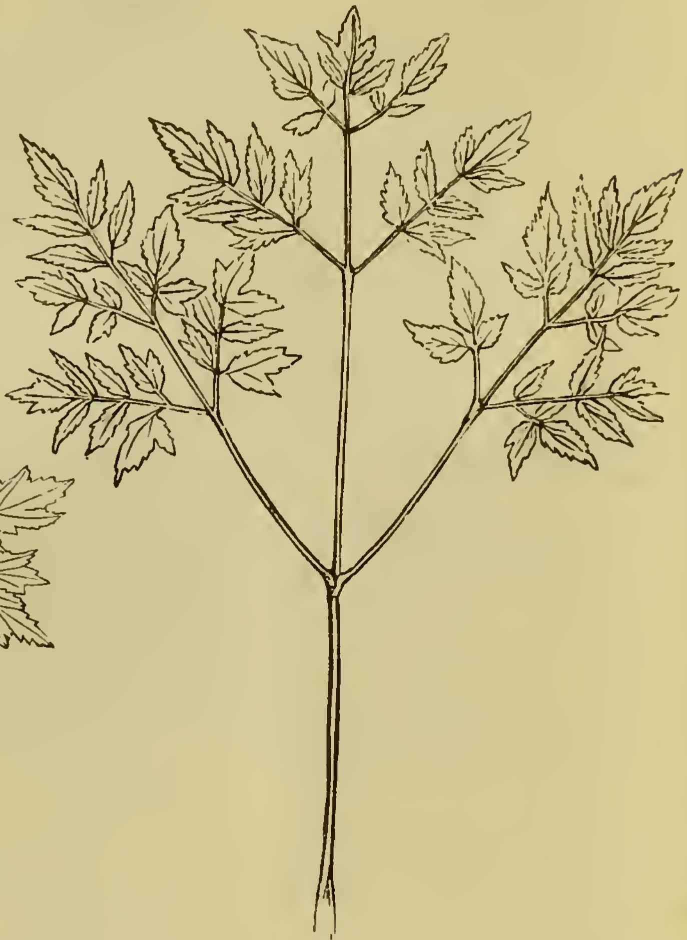

FIG. 189.—Terpinnate leaf of *Thalictrum.*

attached to the common rachis are termed the *pinnæ*, and the secondary leaflets the *pinnules.*[1]

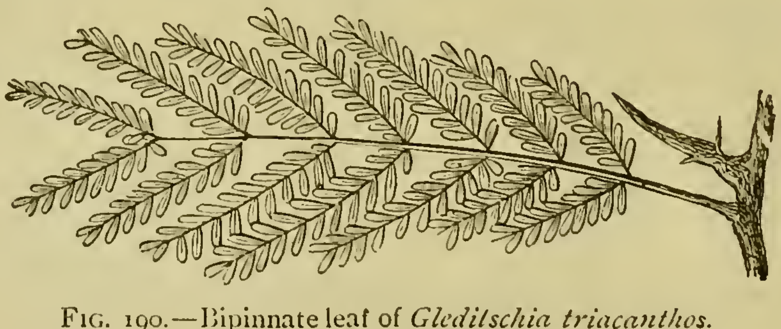

FIG. 190.—Bipinnate leaf of *Gleditschia triacanthos.*

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[1] [Several of the terms now defined, especially those relating to the form of leaves, are necessarily used in slightly different senses by different

All the terms now defined in reference to the attachment, form, incision, and division of simple leaves apply equally to the leaflets of compound leaves.

The disposition and course of the ribs and veins, or the *venation* of leaves, is greatly dependent on the form of the leaf (or perhaps the converse is rather the case). The term principal nerve or *mid-rib* is given to the one which is most strongly developed, and which passes through the centre of the leaf; the larger branches which go out from it are the *lateral ribs*, and the smaller ramifications the *veins* (see Fig. 181, p. 102). If a leaf has only a single unbranched mid-rib, as in many Coniferæ, the venation is said to be simple. If the principal vein, when it enters the lamina of the leaf, divides at once into several branches, the terms *palminerved* (Fig. 191), *pedatinerved* (Fig. 183, p. 102), or *peltinerved* (Fig. 162, p. 96), are given, according to the shape of the leaf. When the mid-rib runs through the leaf to its apex, sending out lateral branches from each side, the leaf is *pinnatinerved* (Fig. 163, p. 97). When several nerves enter the leaf from the stem or petiole, they may be nearly straight and parallel to one another, as in Grasses, or somewhat curved as in the lily of the valley, but are said in either case to be *parallel-veined*. The

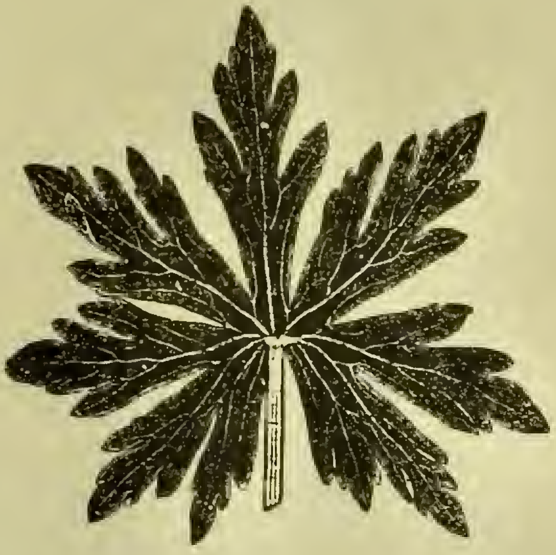

FIG. 191.—Palminerved leaf of *Geranium pratense* (nature-printed).

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writers. They may be combined in a variety of ways, as *linear-lanceolate*, *cordate-ovate*, &c. The following, not mentioned in the text, are also in use among English writers: *deltoid*, with three nearly equal angles; *subulate*, nearly cylindrical and awl-shaped; *apiculate*, ending in a short sharp point; *cuspidate*, with a slenderer sharp point. The margin is *revolute* when turned backwards on to the under side.—ED.]

finest ramifications of veins are found almost without exception in twining plants among Dicotyledons.[1]

The lamina is as a rule flat, rarely *cylindrical* (Fig. 192),

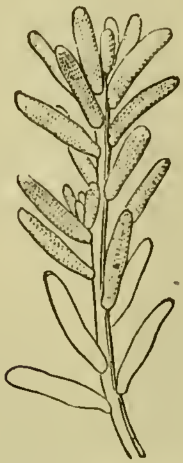

FIG. 192.—Cylindrical succulent leaf of the stonecrop, *Sedum acre.*

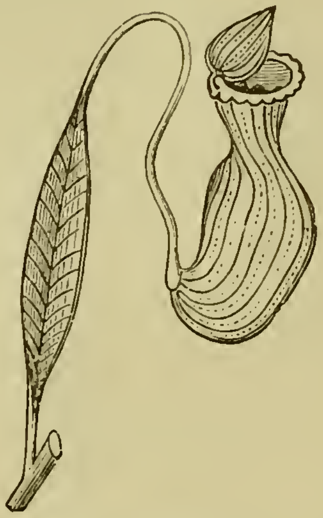

FIG. 193.—Ascidiform leaf of pitcher-plant, *Nepenthes.*

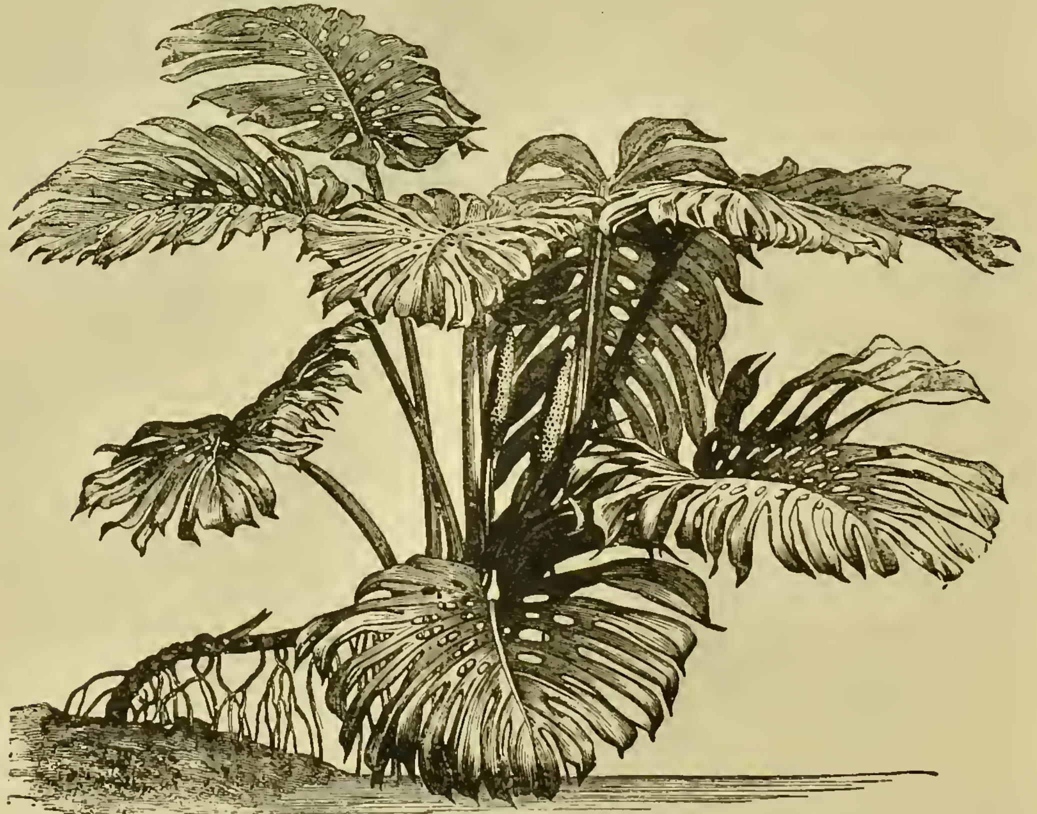

FIG. 194.—*Tornelia fragrans*, an Aroid, with perforated leaves.

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[1] [The parallel venation of the leaves is especially characteristic of Endogens or Monocotyledons; while all the other modes of venation, comprised generally in the term *reticulate* or *net-veined*, are found nearly exclusively in Exogens or Dicotyledons.—ED.]

or *filiform* as in the submerged leaves of *Ranunculus aquatilis* (Fig. 177, p. 100), *fistulose* as in *Allium carinatum*, *inflated* as in the onion, or even *ascidiform*, as in the case of the pitchers of *Nepenthes* (Fig. 193), [and a few other genera, the bladders of *Utricularia* (Fig. 356, p. 184), &c.] Occasionally the lamina is *perforated* (Fig. 194).

It is not uncommon to find on the same plant leaves of different forms (Fig. 177, p. 100; Fig. 195), when the plant is said to be *heterophyllous*. This is especially the case with many water-plants, in which some of the leaves are submerged, while others rise above the water or float upon it, as in the arrowhead, *Sagittaria sagittæfolia*, and water crowfoot, *Ranunculus aquatilis*. The leaves which grow from the lower part of the stem, or *radical* leaves, are frequently different in shape from the upper ones [or *cauline* leaves attached to the stem].

With reference to their consistency, leaves are *herbaceous* [*i.e.* thin and flaccid], *succulent* (Fig. 192) as in the lettuce, *coriaceous* or leathery as in the box or holly, or *fleshy* as in *Pinguicula*.

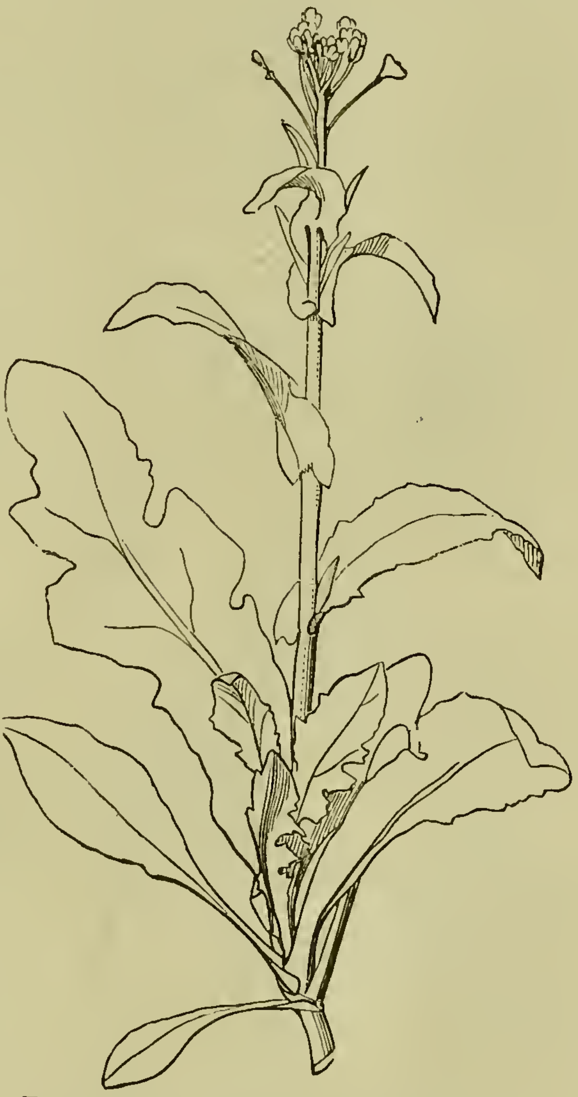

Fig. 195. — Heterophyllous leaves of shepherd's purse, *Capsella bursa-pastoris*.

The leaf is usually of symmetrical shape on each side of the mid-rib; but sometimes *unsymmetrical* or oblique (Fig. 156, p. 95), as in the lime or *Begonia*, one side being larger than the other.

The length of life of leaves varies greatly. The leaves of the majority of plants in temperate climates fall off in the autumn [or are *deciduous*]; in so-called *evergreen* trees and shrubs they persist through the winter, and may even remain for several years, as in some species of Coniferæ.

The green colour which is characteristic of the greater number of leaves is due to a colouring matter contained in their cells, *chlorophyll* (see p. 24). In some etiolated [saprophytic or parasitic] plants, as *Orobanche*, it is wanting; in others the leaves are variegated or coloured white, red, or yellow, in patches. The colour of the leaves of many plants changes more or less in the course of the year. Thus the leaves of the grape-vine, which are at first green, often turn red in the autumn; while those of the copper-beech are reddest in the spring, and afterwards become more and more green.

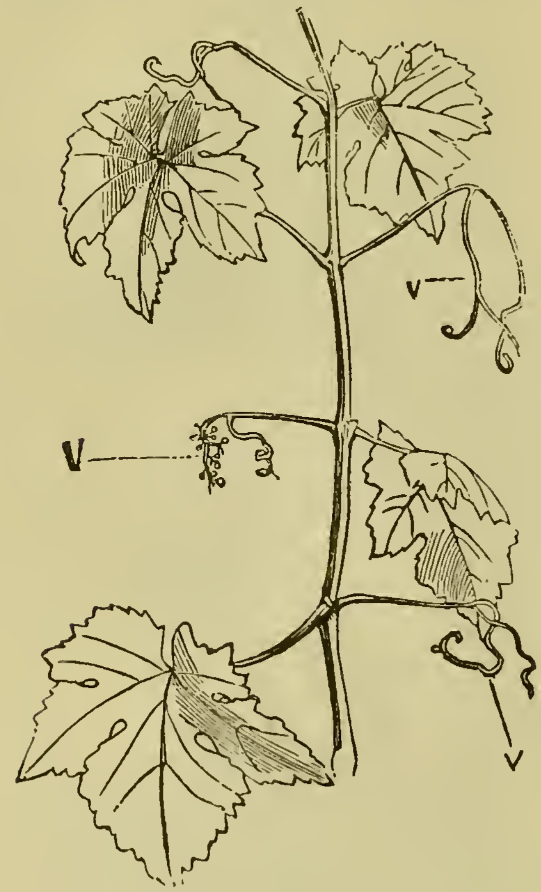

Fig. 196.—Stem-tendrils of the grape-vine; *v* in the normal state; V bearing a bunch of grapes.

SUBSIDIARY ORGANS.

Under this head are included a number of structures which may be regarded as appendages to the organs already described. They are in some cases modified parts of the stem or leaf, in others a special development of the epidermis which forms the outer covering of plants. Among them are *tendrils* or *cirrhi*, filiform structures which cling round neighbouring substances, and whose function is to enable weak plants to attach themselves to, and to climb up stronger plants. Accordingly as they belong to the stem as in the vine (Fig. 196), or to the leaf as in the tare, they are called *stem-* or *leaf-tendrils*. The same distinction is made between *branch-spines* as in the sloe (Fig. 197), and *leaf-spines* as in the holly (Fig. 172, p. 98); *i.e.* stiff and very sharp-pointed structures arising from the transformation of a stem or leaf, or a part of one of these organs, and which are therefore not mere epidermal growths.[1] *Prickles*, although sharp-pointed like spines, are distinguished from them by belonging to the epidermis only, and therefore easily breaking off smoothly, which is never the case with spines; a good illustration is furnished by the rose (Fig. 198; see also p. 63). An important class of these subsidiary organs are *hairs*—delicate appendages of the epidermis which are

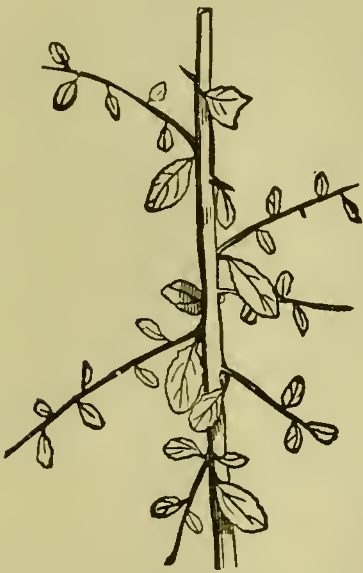

FIG. 197.—Branch-spines of the sloe, *Prunus spinosa*.

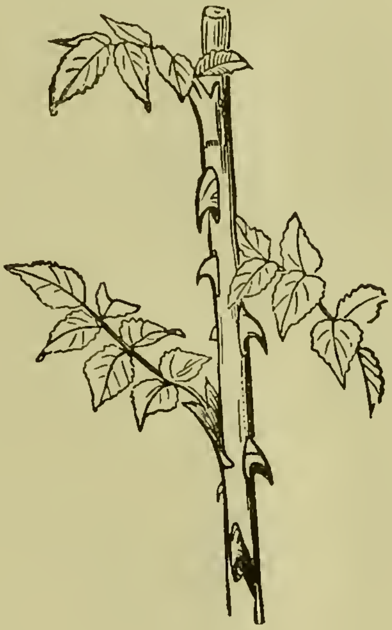

FIG. 198.—Prickles of the rose.

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[1] [Tendrils and spines may also both be metamorphosed stipules; the former is generally believed to be the morphological nature of the tendrils in the Cucurbitaceæ; the latter is the case in the 'acacia-tree,' *Robinia* (Fig. 184, p. 103). In *Lathyrus Aphaca* (Fig. 146, p. 92), the whole of the leaf is converted into a tendril; but more frequently only the upper pinnæ of a compound leaf, as in many Leguminosæ, or the extended mid-rib, as in *Gloriosa*.—ED.]

sometimes very thinly scattered, when [if they are moderately stiff] the part which they cover is said to be *setose* or *hispid*, *hirsute* [when the hairs are longer], *pubescent*, or *villous* [when the hairs are thicker and softer, according as they are shorter or longer]; *silky* [when they are very long and delicate] as in the young leaves of the aspen ; *woolly* as in some species of *Primula* ; *tomentose* as on the underside of the leaves of the aspen, or *floccose*, as in *Verbascum Thapsus* [when they are very dense and interwoven, according to the coarseness of the hairs and the thickness of the coat which they form]. Sometimes, as in the stinging-nettle (Fig. 88, p. 62), the hair contains an acrid fluid, and is then called a *sting* ; if the fluid, on the other hand, is viscid [or oily], it is termed a *glandular hair* (Fig. 92, p. 63). Closely connected with these are *glands*, organs which do not assume the form of a hair, but, like glandular hairs, secrete a fluid which causes the surface to become viscous or glutinous as in *Lychnis viscaria* (see also p. 63). Mention should be made finally of *scales* [or *peltate hairs*], peculiar flattened hairlike structures, such as occur on the leaves of *Elæagnus* (Fig. 91, p. 63), and *Hippophaë rhamnoides.*

THE FLOWER.

The flower is the organ [or rather assemblage of organs] the purpose of which is the production of the seed. It is therefore the reproductive organ of the plant, and is morphologically a branchlet provided with leaves of peculiar form.

The more or less perfect development of the flower-stalk determines whether the flower is *pedicellate* (stalked) or *sessile.*

Some parts of the flower are essential, others non-essential, according as they are indispensable or not for its main purpose, the production of the seed. The non-essential parts, which are always exterior, form together the floral envelopes or *perianth*, and are separately the *calyx* and *corolla*, the former constituting an outer whorl, which is usually green, and the latter an inner whorl, which is usually coloured (*i.e.* not green), (Fig. 199). In other cases, however, there is no such contrast between the two whorls. One may be entirely absent, as in the elm [or stinging nettle], or, if both are present, as in Liliaceæ, [Juncaceæ], and Orchideæ, they may not materially differ in colour or form; and the term *perianth* is especially used in reference to these cases. The essential parts of the flower are the *andrœcium* or *stamens*, and the *gynæceum* or *pistil* (Fig. 200, s, St).

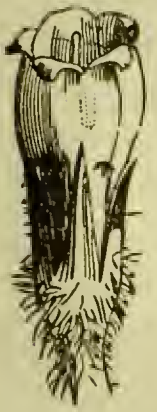

Fig. 199.—Flower of *Symphytum officinale*, with both calyx and corolla.

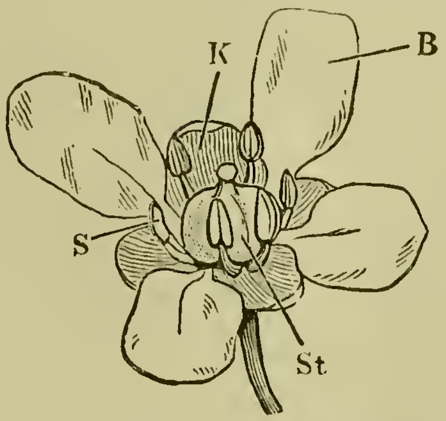

Fig. 200.—Flower of *Sisymbrium Alliaria* (magnified); K calyx; B corolla; S stamens; St pistil.

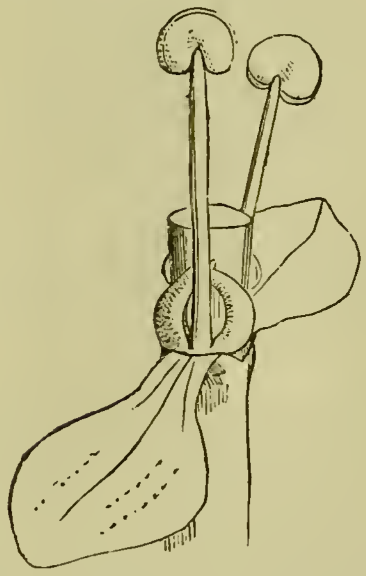

Fig. 201.—Staminate (♂) flower of *Callitriche verna* (greatly magnified) with two sickle-shaped bracts.

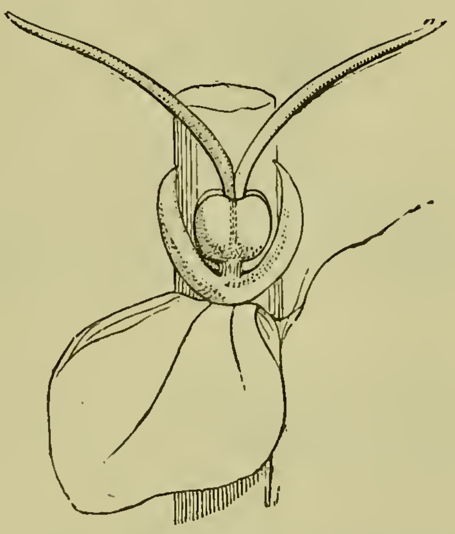

Fig. 202.—Pistillate (♀) flower of *Callitriche verna* (greatly magnified).

The *fruit*, containing the *seeds*, is developed out of the latter or female organ, after fertilisation by the *pollen* formed in the stamens or male organs.

When all these four organs are present in the same flower, it is said to be complete or *perfect*; if either is absent, incomplete or *imperfect*. [If calyx and corolla are both absent, the flower is said to be *achlamydeous*; if the calyx is present, but the corolla wanting, it is *monochlamydeous* or *apetalous*; while if both whorls are present, it is *dichlamydeous*.] Those flowers which possess both stamens and pistil are *hermaphrodite* or *bisexual*; those in which either stamens or pistil are wanting are *diclinous* or *unisexual*. If the stamens are present but the pistil absent, they are *male* or *staminate* (Fig. 201); if on the other hand the pistil is present but the stamens absent, they are *pistillate* or *female* (Fig. 202); while flowers which possess neither pistil nor stamens, as the outermost flowers of the capitula of the corn blue-bottle, *Centaurea Cyanus* (Fig. 203), are sterile or *neuter*. If the same plant bears both male and female flowers, the species and the flowers are said to be *monœcious*; *diœcious* when the male and female flowers are on different individuals, and hence some individuals are male, others female; while those plants in which male, female, and hermaphrodite flowers are all found on the same individual are said to be

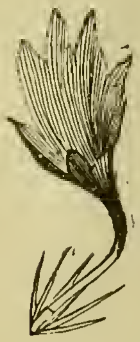

FIG. 203.—Neuter flower of *Centaurea Cyanus*.

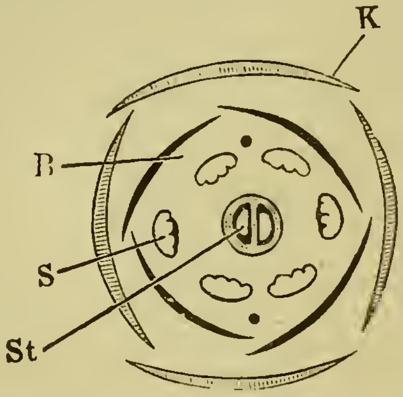

FIG. 204.—Floral diagram of a cruciferous flower; K calyx; B corolla; S stamens; St bilocular ovary (see also Fig. 200).

polygamous. Examples of monœcious plants occur in the oak, walnut, birch, and *Callitriche*; of diœcious plants in the juniper and poplar; of polygamous in the maple, elm, and horse-chestnut.

The centre of a perfect flower is occupied by the pistil, around which are grouped first the stamens, next the corolla, and finally the calyx, arranged in whorls or spiral lines. The greatest diversity, however, prevails in the mutual position of the individual organs, which is best recognised by a longitudinal section of the flower, and by the *floral diagram* or cross section. In Fig. 204, for example, which represents diagrammatically the cross section of a cruciferous flower, it is seen that the calyx, K, consists of two whorls, each of two leaves, with alternate æstivation; the corolla, B, of one whorl of four leaves with imbricate æstivation; while the andrœcium, S, also consists of two whorls, the outer one of two, the inner one of four stamens. The leaves of the corolla alternate with those of the calyx; the stamens of the inner whorl stand in front of (in other words, are opposite to or superposed upon) the leaves of the corolla, the two outer ones being

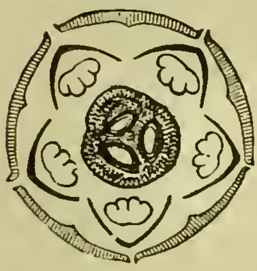

FIG. 205.—Diagram of the flower of *Rhamnus Frangula*; with five valvate sepals, five folded petals, five stamens opposite the petals, and a trilocular ovary.

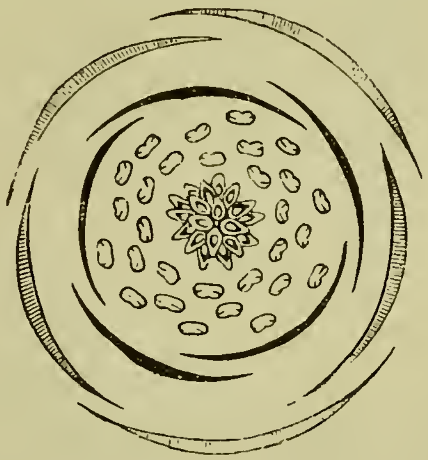

FIG. 206.—Diagram of the flower of *Ranunculus acris*; with five imbricate sepals, five imbricate petals alternate with the sepals (both quincuncial), a very large number of stamens, and a large number of distinct carpels.

alternate with them. The diagrams Figs. 205, 206[1] bring out analogous points of structure.

All the different parts of the flower frequently stand free on the base or *receptacle* of the flower, as in the various species of *Ranunculus*, but are often *coherent* or *adherent* to one another. Thus in the dead-nettle, borage, &c., the stamens are adherent to the corolla, and in *Daphne* (Fig. 207) to the perianth; in the Malvaceæ (Fig. 275, p. 139) the filaments of the stamens are coherent in their lower part into a tube; in Orchideæ the single stamen is adherent to the pistil, &c. When the calyx, corolla, and stamens adhere to one another at their base, the flower is said to be *calycifloral* (Fig. 208); *thalamifloral* when the various parts stand free on the receptacle or *thalamus* (Fig. 209).

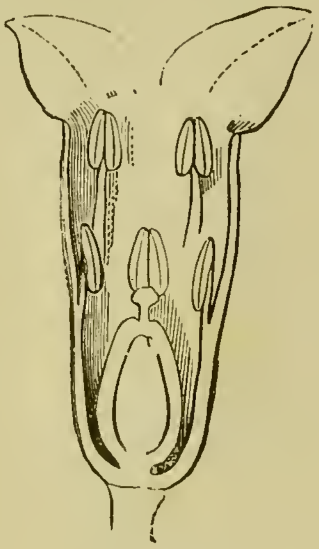

FIG. 207. — Longitudinal section through the flower of *Daphne Laureola*, showing the stamens adherent to the perianth.

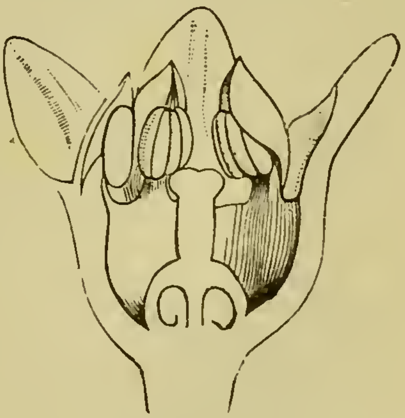

FIG. 208.—Longitudinal section through the flower of *Rhamnus Frangula*, showing the lower part of the calyx, corolla, and stamens adherent to one another.

Special importance is attached to the relative positions of the perianth-whorls and stamens in relation to the pistil, or to their *insertion*; the ovary [the lower part of the pistil] being *inferior* or *superior* in relation to the superior or inferior calyx, corolla, and stamens. Thus the ovary is superior or free, as in *Ranunculus* (Fig. 209) or *Rhamnus* (Fig. 208), when the remaining parts of the flower are attached to or below its base, and are conversely inferior or *hypogynous.* The ovary on the other hand is inferior when the other parts of the flower are attached to its upper part, and are therefore superior, adherent, or *epigynous*, as in *Mesembryanthemum* (Fig. 210). The ovary, finally, is *half-inferior* when the other parts of the flower are coherent at their base, and thus form a tube which surrounds the free pistil, as in the rose; the calyx, corolla, and stamens then having a half-superior or *perigynous*[1] insertion.

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[1] In all the diagrams, the calyx is shaded a lighter colour than the corolla.

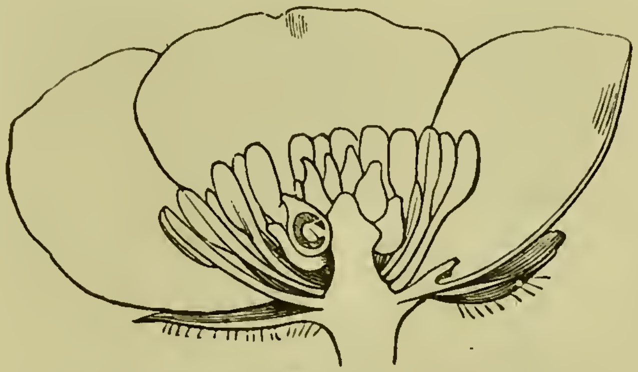

FIG. 209.—Longitudinal section through the flower of *Ranunculus acris*, showing the hypogynous calyx, corolla, and stamens.

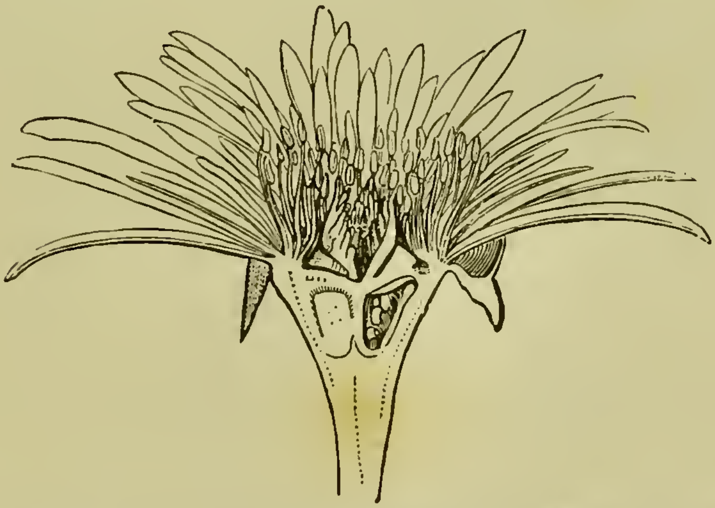

FIG. 210.—Longitudinal section through the flower of *Mesembryanthemum falciforme*, showing the epigynous calyx, corolla, and stamens.

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[1] [Practically the term *perigynous* is used in English descriptive botany with reference to the stamens to express their union to the calyx; when attached to the corolla they are *epipetalous*; *epigynous* when attached to the upper part of the ovary. An 'inferior' ovary is always the result of the adhesion to the wall of the ovary of a part or the whole

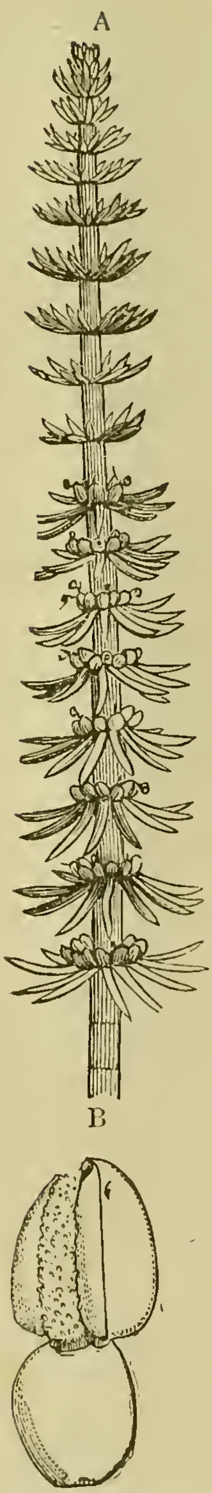

FIG. 211.—A *Hippuris vulgaris* with verticillate inflorescence; B separate flower consisting of a pistil with a long wart-like stigma and a single stamen (magnified).

An additional point to note is that frequently the number of the different parts of the flower is not always the same in the same species. Thus in *Adoxa Moschatellina* and *Monotropa hypopitys*, the petals of the terminal flowers of the inflorescence are five in number; of the lower flowers on the contrary four; in *Atriplex* the perianth of the female flowers is two-leaved, while that of the male and hermaphrodite flowers is three to five-leaved.

THE INFLORESCENCE.

The flowers stand either solitary or grouped together according to a definite law, on branched or thickened flower-stalks. Such a group of flowers is termed an *inflorescence*; [the common stalk of the inflorescence is then the *peduncle*, the separate stalks of the individual flowers *pedicels*, and the axis of the inflorescence the *rachis*]. *Solitary* flowers are usually seated each in the axil of a leaf or *bract* as in the deadly nightshade, *Atropa Belladonna*, less often at the apex of the stem as in *Paris quadrifolia*, or of a scape as in the tulip. In some plants with verticillate leaves a single flower is produced in the

of the calyx; when the whole is adherent, the calyx-limb is then *obsolete*, as in many Umbelliferæ; when only a portion, then the calyx-limb is said to be superior, or half-superior, as the case may be. The term *cohesion* is used to express the union of similar parts, as stamens with stamens, or petals with petals; *adhesion* the union of dissimilar parts, as stamens with corolla, or calyx with ovary. In German the same term is used for both.—ED.]

axil of each of the leaves, when the flowers form a true *whorl*, as in *Hippuris* (Fig. 211).

The common peduncle of the inflorescence is sometimes extremely abbreviated, the sessile or very shortly pedicelled flowers standing upon it very closely crowded, as in the clover (Fig. 212). The form of the inflorescence is then dependent on the nature of the termination of the peduncle.

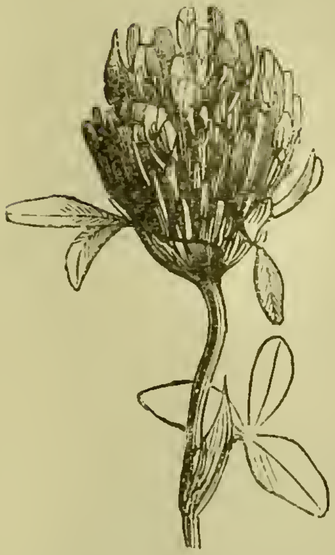

Fig. 212. — Abbreviated inflorescence of clover.

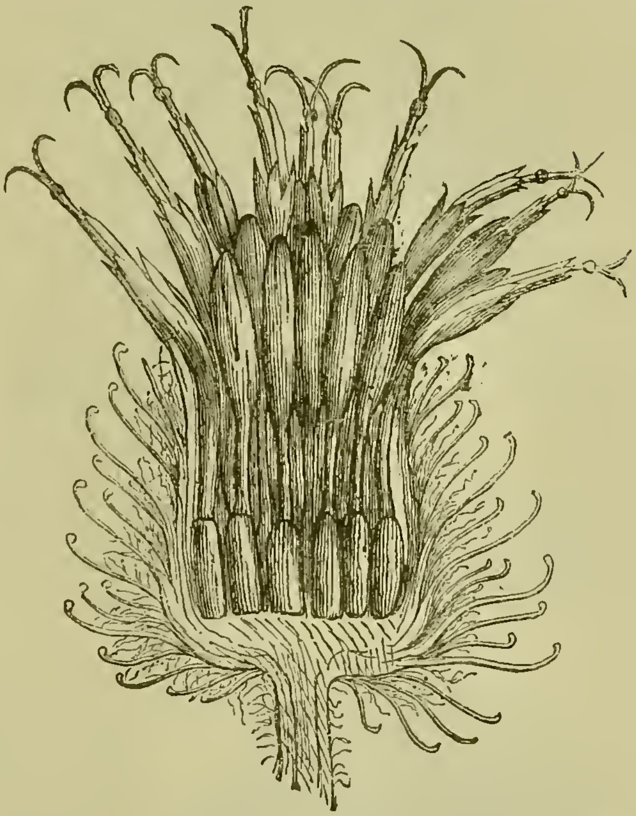

Fig. 213.—Longitudinal section through the capitulum of the burdock, *Arctium Lappa.*

The *common receptacle*, or surface from which the inflorescence springs, is sometimes flattened out, and sometimes swollen into a more or less hemispherical form (Figs. 213, 214); these two variations being especially common in the order Compositæ, and characterising the *capitulum*; or it is sometimes hollowed out into a pitcher-like form, as in the fig (Fig. 215), constituting a *hypanthodium*; or the separate flowers are buried in the fleshy receptacle, when it becomes a *cœnanthium*, as in *Dorstenia* (Fig. 216). The receptacle itself is usually solid, but may be hollow (Fig. 214);

it may be *naked*, or *setose*, *i.e.* clothed with bristles (Fig. 217), or covered with hair-like bracts or *paleæ* when it is *paleaceous* (Fig. 218), or *fimbriated*; or it may be *pitted* with small excavations. All these forms of receptacle occur in different genera of Compositæ. The capitulum is most commonly—in Compositæ [and Dipsacaceæ] always—enclosed at its base in a common *involucre*, consisting of crowded bracts, sometimes arranged in several whorls, and then

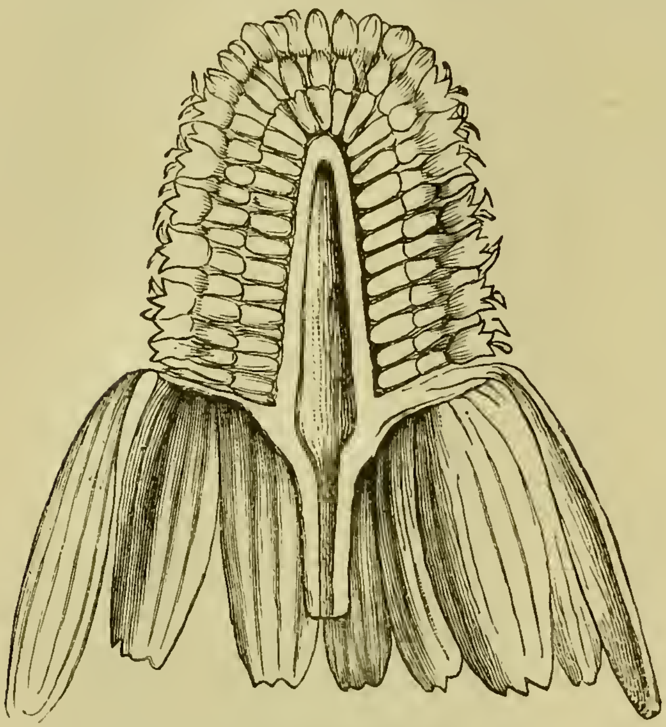

Fig. 214.—Longitudinal section through the rayed capitulum of the chamomile with hollow receptacle, the outer flowers of the ray ligulate, the inner flowers of the disc tubular (magnified).

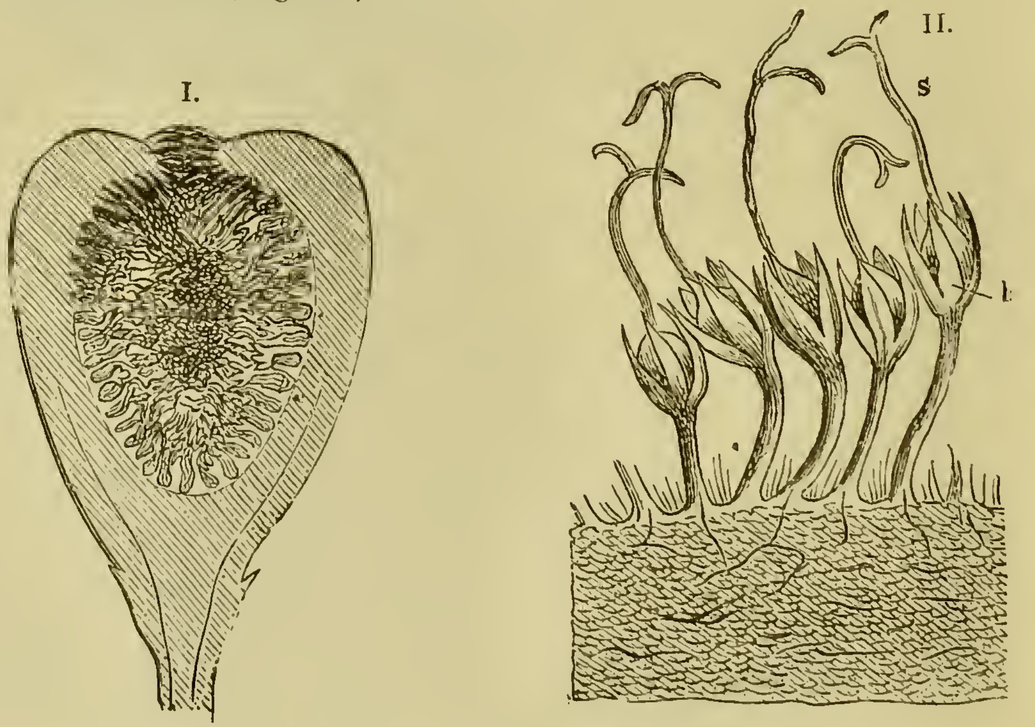

Fig. 215.—I. Longitudinal section through the hypanthodium of a fig, exposing the flowers in its interior; II. a piece greatly magnified, with five female flowers; *s* pistil; *b* perianth.

usually imbricate (Fig. 219). In many plants (especially Compositæ) in which the flowers are arranged in capitula,

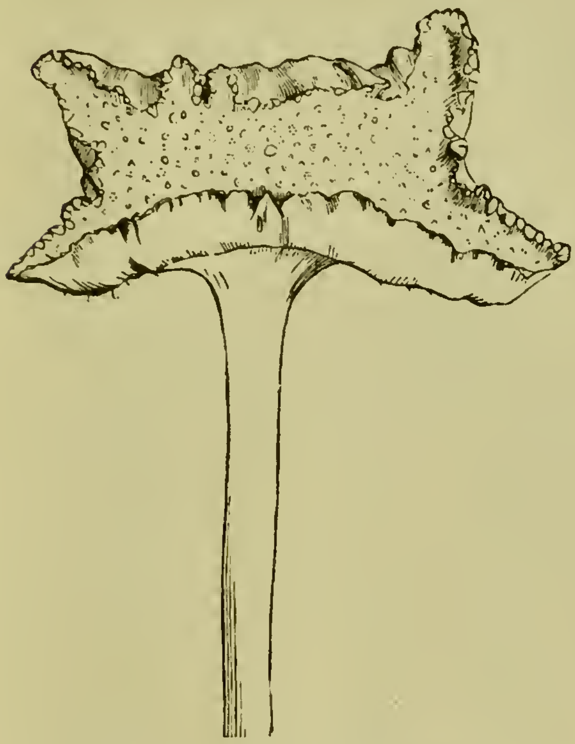

FIG. 216.—Fleshy cœnanthium of *Dorstenia*.

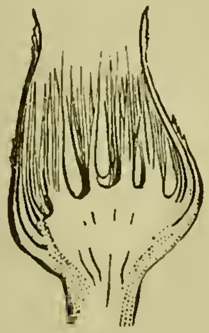

FIG. 217.—Common receptacle of *Centaurea Cyanus* with setose paleæ.

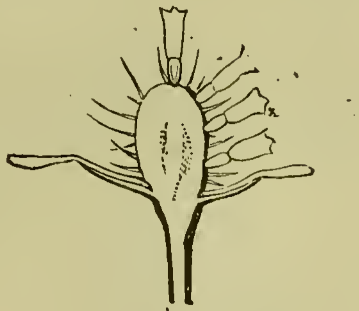

FIG. 218.—Common receptacle of *Anthemis arvensis* with paleæ between the flowers.

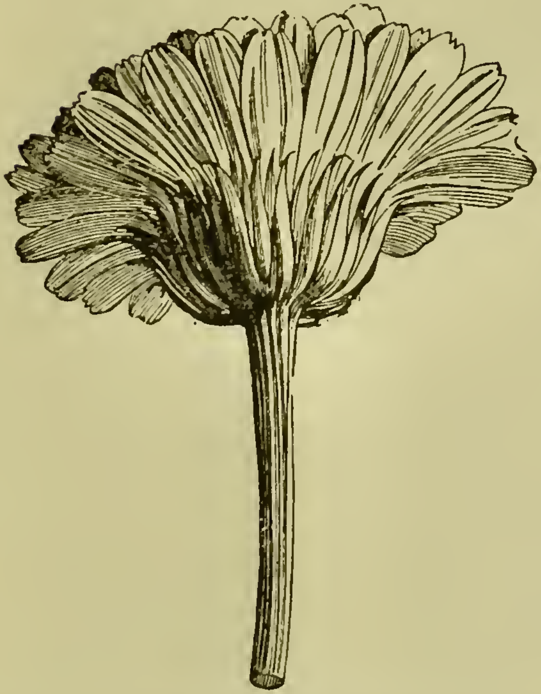

FIG. 219.—Capitulum of marigold, with imbricate involucre.

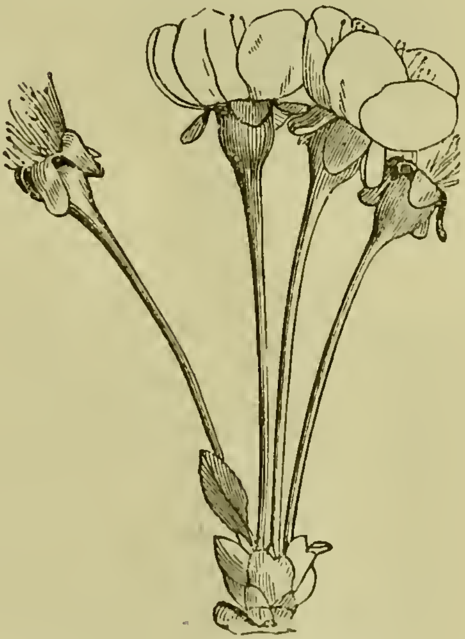

FIG. 220.—Simple umbel of the cherry.

the marginal flowers of each capitulum are larger and more conspicuous than the internal ones, and the capitulum is then said to be *rayed* [the outer flowers being termed flowers or *florets of the ray*, the inner ones flowers or *florets of the disc*], as in the chamomile (Fig. 214), single aster, marigold, &c.

The *umbel* resembles the capitulum in the fact of the stem terminating in a number of flowers, but each separate flower is stalked. The umbel is *simple* when the main stem or peduncle ends in a number of separate stalked flowers, as in the cherry (Fig. 220), *compound* when it branches into a number of *secondary umbels* or *umbellules* (Fig. 221) [as in the majority of genera of Umbelliferæ]. The main umbel is generally surrounded at its base by a whorl of bracts, again called an *involucre*, while the whorl surrounding each of the secondary umbels is an *involucel* or partial involucre. Either of the two may, however, be wanting, or may consist of a smaller or larger number of leaves. Thus the carrot has both involucre and involucels, each consisting of a large number of bracts ; the fool's parsley, *Æthusa cynapium* (Fig. 221), has involucels, but no general involucre; the fennel neither one nor the other. The length of the separate pedicels may vary greatly, so that the umbel becomes spherical, hemispherical, or flat ; or it may be rayed like the capitulum [as in *Heracleum*, where the outer flowers of each umbellule are larger than the inner ones].

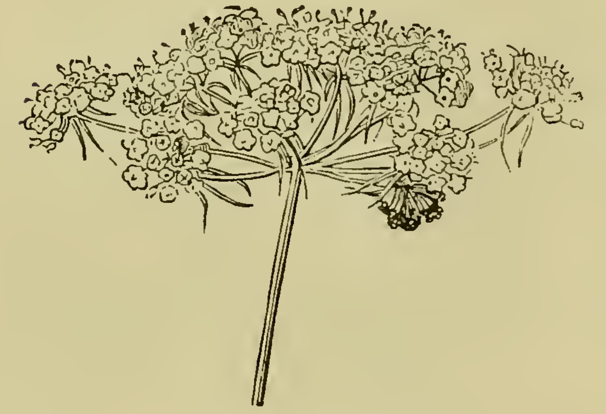

FIG. 221.—Compound umbel of fool's parsley, *Æthusa cynapium* ; common involucre wanting ; involucels of three leaves each.

In the *spike*, the common peduncle or rachis bears a number of flowers, arranged, in the simple spike (Fig. 222) opposite one another, in whorls, or spirally, and sessile, or with only very short pedicels ; while, in the *compound spike*, these are replaced by small secondary *spikelets*, as in some grasses. The individual flowers may also be less or more crowded, according to the greater or less elongation of the rachis. A spike with a thick fleshy rachis, and enveloped in a large bract growing at its base, as in *Arum* or *Calla*, is termed a *spadix*, and the enveloping bract a *spathe*. A *catkin* or *amentum* is a crowded spike of unisexual flowers, with weak rachis (Fig. 223); when consisting of male flowers only it is deciduous; the male flowers of the oak, hazel, sweet chestnut, &c., are in catkins; both male and female flowers of the willow, poplar, and birch. In the *cone* of many Coniferæ (Fig. 224), the rachis and bracts which subtend the naked ovules have become more or less completely lignified; in the *strobilus* of the hop the bracts are persistent, large, and membranous.

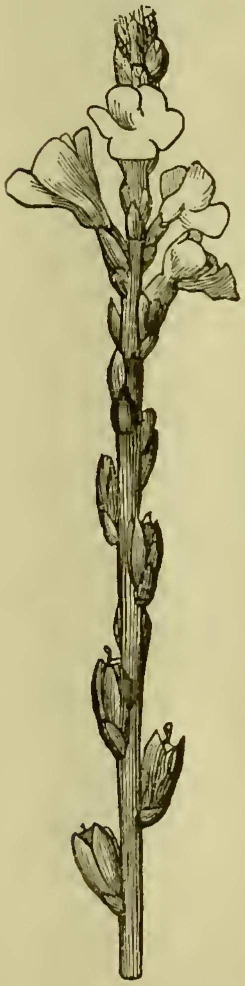

FIG. 222. — Simple spike of *Verbena officinalis*.

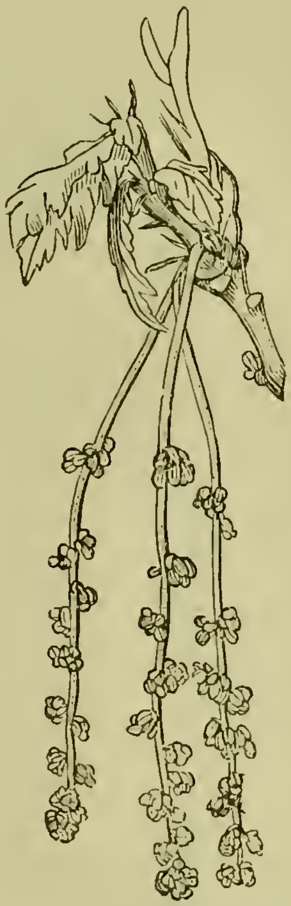

FIG. 223.—Catkin or amentum of the oak.

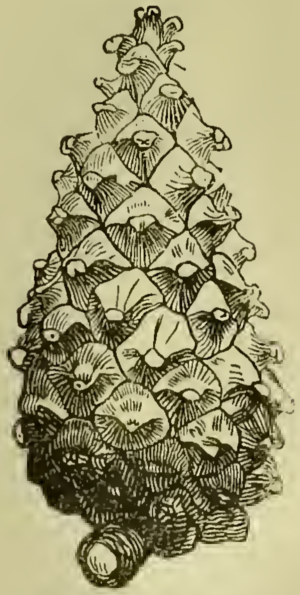

FIG. 224. — Cone of the Scotch fir.

The *raceme* is distinguished from the spike by its separate flowers being stalked. A compound raceme or *panicle*, as in the oat, is distinguished from a simple raceme (Fig. 225) by the individual flowers on the rachis being replaced by secondary racemes; when very much branched [and pyramidal in shape] as in the lilac [or horse chestnut] it is called a *thyrse.* When the lower and outer flowers are borne on pedicels which are so much longer than the upper and inner ones that the whole inflorescence is more or less nearly flat-headed, it becomes a *corymb*, as in the undeveloped raceme of many Crucifers [like the wall-flower, or in the elder]. In the inflorescences of many species of *Juncus* and *Luzula* the pedicels of the lower flowers are so greatly lengthened that they rise even above the upper ones, and the term *anthela* is then given to the inflorescence. The mode of development of the anthela corresponds to that of the sympodium (see p. 76). The panicle often passes over insensibly into the compound umbel. In the *cyme* two or more branches of equal strength spring from beneath a terminal flower; it

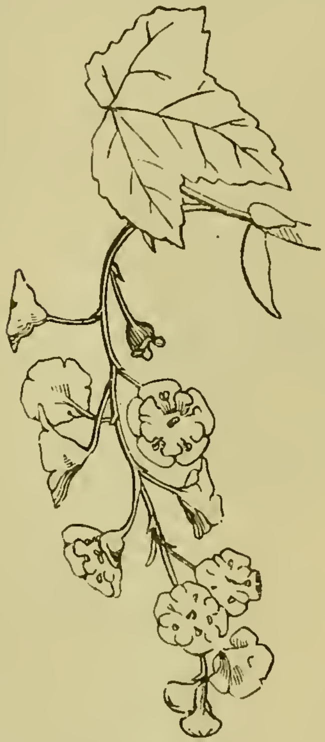

FIG. 225.—Simple raceme of the currant.

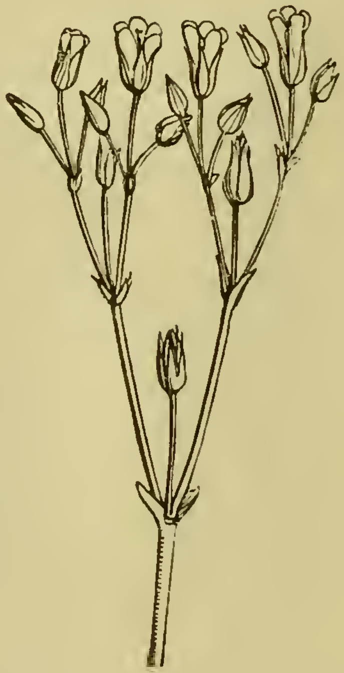

FIG. 226.—Dichotomous cyme of *Cerastium.*

is globular in the guelder-rose, flat-headed or corymbose in the laurustinus. Under this head should be included also the *verticillaster*, frequently erroneously described as a whorl, a very common inflorescence in the Labiatæ, in which the flowers of two cymes, often but imperfectly developed and borne on opposite sides of the stem in the axils of opposite leaves, appear as if encircling the stem. Similar undeveloped closely crowded cymes, termed *glomeruli*, occur in *Valerianella*. When a cyme is developed only on one side, and in the young state is rolled up in a circinate manner, it is called a *scorpioid cyme*, as in the forget-me-not (Fig. 227); [when always branching into two arms of equal strength, with a flower in the angle, as in most Caryophyllaceæ, it is a *dichotomous cyme*, Fig. 226]. The great variety of different kinds of inflorescence is increased and rendered more complicated by the combination of some of those here described.[1]

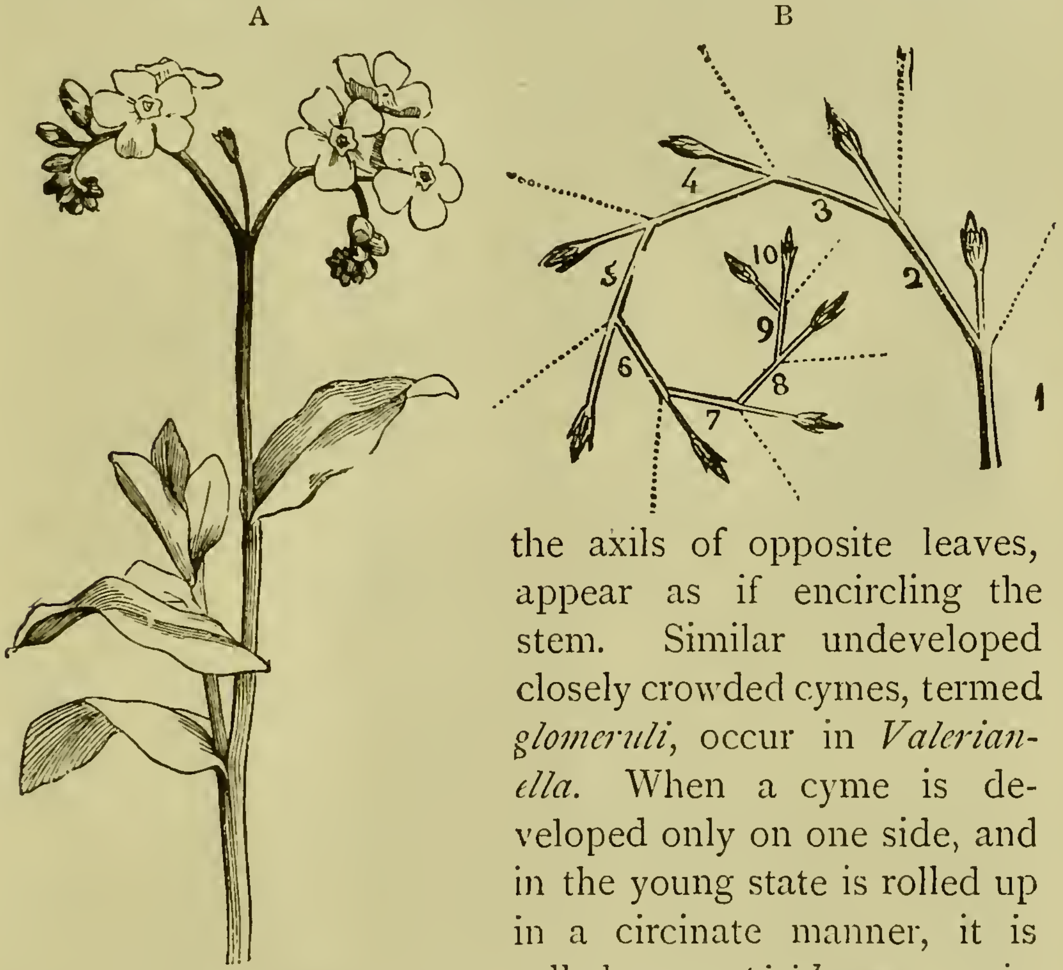

FIG. 227.- A, Cymose inflorescence of *Myosotis*; B, diagrammatic representation of the order of development of the flowers in the scorpioid cyme.

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[1] [The best primary classification of inflorescences is into (1) *indefinite* or *centripetal*, in which the lowest flower or that furthest from the

THE CALYX.

The calyx is, in its most perfect form, the protecting envelope for the interior more delicate parts of the flower; and may therefore be compared to bud-scales. In some plants, as in the Umbelliferæ, it is but slightly developed, the calyx-limb being obsolete, and its teeth scarcely visible on the margin of the inferior ovary.[1] The more perfectly developed calyx, which is generally green, consists usually of only a single whorl of leaves or *sepals*; less often, as in the strawberry (Fig. 228), of two; or occasionally, as in *Gossypium*, of three whorls. In a few instances—among Dicotyledons in the fuchsia, larkspur, *Tropæolum*, &c.—the calyx is coloured; but the whole of the floral envelope might in these cases be spoken of as a perianth, as is usually the case with Monocotyledons.

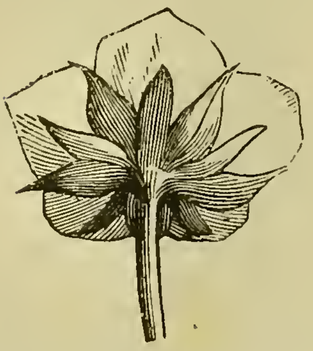
FIG. 228.—Flower of the strawberry, with calyx in two rows.

The calyx is said to be *gamosepalous* or *synsepalous* [in older works on descriptive botany 'monosepalous'], when the leaves of which it is composed are more or less coherent at the base; *aposepalous* or *eleutherosepalous* [in older works 'polysepalous'], when they are completely distinct. It may also be *regular* or *irregular*; but the irregular calyx is almost always *symmetrical*,[2] that is, it can be divided into two

apex opens first, and then the rest in regular succession; and (2) *definite* or *centrifugal*, in which the order of development is the reverse, the central flower opening first. To the second class belong the cyme and its varieties; to the first most of the other kinds of inflorescence. In the capitulum of some Dipsacaceæ we get a combination of the two.—ED.]

[1] See note, p. 115.

[2] [This term is used in most English text-books in a different sense, to express a relationship in number between the sepals, petals, and stamens. If these are the same in number, or a multiple of the same number, as in *Saxifraga*, 5, 5, 5, or *Fuchsia*, 4, 4, 8, the flower is said to be 'symmetrical;' if this is not the case, as in Cruciferæ, 4, 4, 6, or Labiatæ, 5, 5, 4, it is said to be 'unsymmetrical.'—ED.]

parts, so that each one is exactly similar to the other reversed. The regular gamosepalous calyx may be *rotate* [or with the limb expanded like a wheel], *turbinate* or top-shaped, *urceolate* or urn-shaped (Fig. 229), *infundibuliform* or funnel-shaped, *tubular* or cylindrical, *inflated* (Fig. 254, p. 132), [*campanulate* or bell-shaped], &c. The margin or edge of the calyx may also be *toothed*, *lobed*, or *incised*, according to the depth to which it is cut. The number of teeth has also to be taken into account, when the calyx is said to be *bifid*, *trifid*, *multifid*, &c. ; or in the case of aposepalous calices the number of separate sepals, when it is *bisepalous*, *trisepalous*, *polysepalous*, &c. Among irregular forms of the calyx an especially common one is the *bilabiate*, or two-lipped (Fig. 230), a gamosepalous calyx divided by two deep incisions into an upper and lower division or lip [particularly characteristic of the order Labiatæ] ; and not unfrequent are the *spurred* (Fig. 231), furnished with a larger or shorter hollow appendage or spur [as in *Tropæolum* and *Impatiens*] ; and the *saccate* (Fig. 232), which occurs frequently in Cruciferæ, and consists of four distinct sepals, two of which are gibbous at the base.

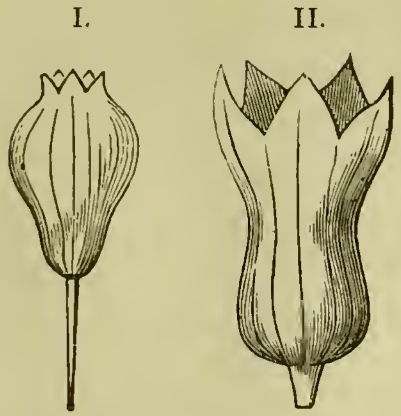

FIG. 229.—I. Turbinate ; II. urceolate calyx (represented diagrammatically).

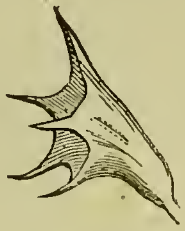

FIG. 230.—Bilabiate five-toothed calyx of *Lamium*.

As respects its persistence, the calyx may be *caducous*, when it is thrown off at the time of expansion of the flower, as in the poppy (Fig. 233) ; *deciduous*, when it falls off at the same time as the corolla; or *persistent* [when it remains after the corolla has fallen]. The calyx generally leaves a smooth scar when it falls off; less often, as in *Datura* and *Portulaca*, the lower part remains attached like a frill. The persistent calyx often retains its form unchanged, as in the strawberry; but, sometimes, as in the winter-cherry, *Physalis Alkekengi* (Fig. 234), it increases in size [or is *accrescent*], and forms a membranous sack which envelopes

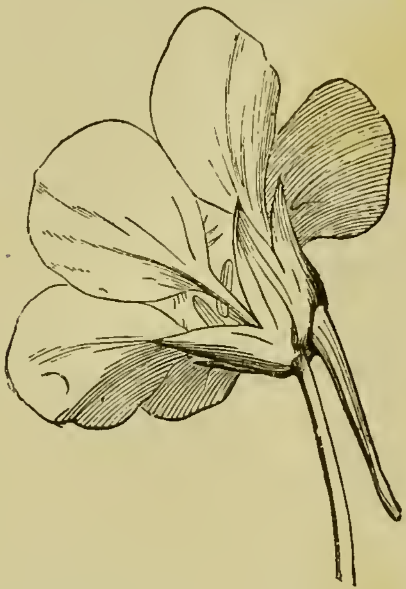
FIG. 231.—Spurred calyx of *Tropæolum.*

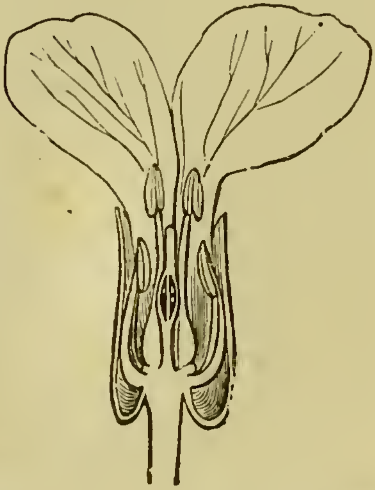
FIG. 232.—Saccate calyx of *Lunaria.*

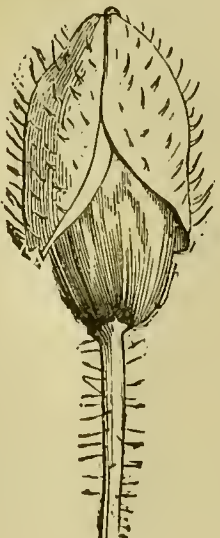
FIG. 233.—Caducous calyx of poppy.

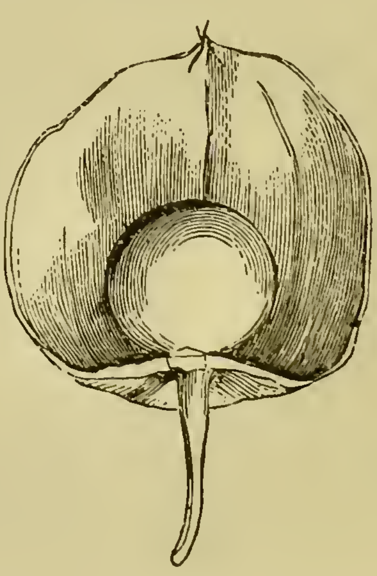
FIG. 234.—Longitudinal section through the accrescent calyx of *Physalis Alkekengi* surrounding the fruit.

the fruit. Sometimes it even takes part in the formation of the fruit, as in *Trapa*, the four horns of the fruit being here formed by the lignification of the calyx-teeth.[1] Particularly noteworthy is the production of the *pappus* from the limb of the calyx. This peculiar form is especially characteristic of Compositæ; the calyx continues to grow after the withering of the corolla, and either a crown of simple hairs or *pilose* pappus (Figs. 235, 236), or a *plumose* pappus of branched hairs

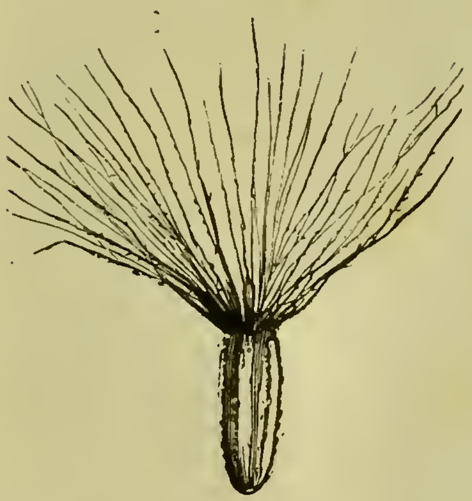

FIG. 235.—Pilose sessile pappus of *Senecio.*

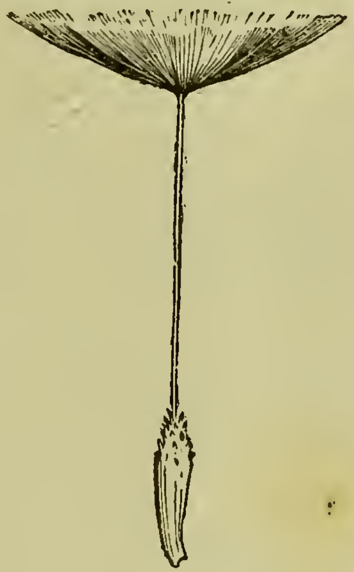

FIG. 236.—Pilose stipitate pappus of dandelion.

(Figs. 237, 238), is formed from its teeth, and subsequently crowns the fruit. The pappus may either be *sessile* as in the groundsel (Fig. 235), or *stipitate* as in the dandelion (Fig. 236), from the development of the upper part of the calyx-tube, in the form of a stalk which bears the feathery crown. The pappus, again, may be *dentate*, or *coronate* (Fig. 239), the calyx-teeth remaining in the latter case undeveloped, and being transformed into small broad hairs which form, as it were, a crown to the fruit. In addition to the Compositæ, instances of a pappus occur in Valerianaceæ and Dipsacaceæ. The chicory, *Cichorium*

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[1] [The fleshy calyx-tube—or, as some think, the receptacle—of the rose, apple, pear, &c., unites with the pistil to form a pseudocarp (see p. 146).—ED.]

Intybus, furnishes an illustration of a coronate, the artichoke and *Scorzonera* of a plumose sessile, the goatsbeard, *Tragopogon*, of a plumose stipitate, the common thistle, *Cnicus*, of a pilose sessile, the dandelion of a pilose stipitate pappus.

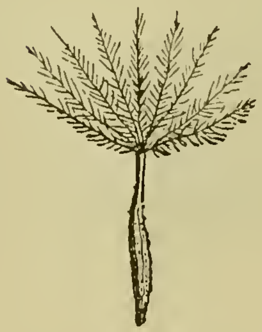

Fig. 237. — Plumose sessile pappus of *Tragopogon*.

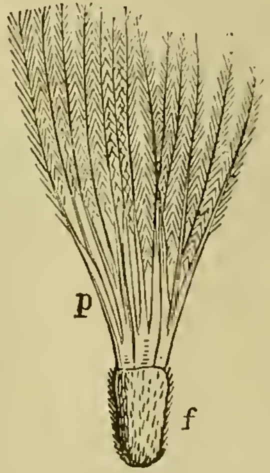

Fig. 238.—Pappus of *Carlina vulgaris*, the feathery rays united below into several bundles and coherent at the base into a ring.

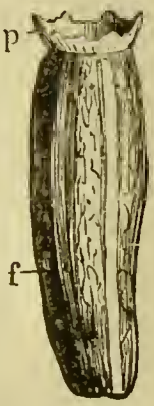

Fig. 239.—Fruit, *f*, of the tansy, *Tanacetum vulgare*, surmounted by the coronate pappus, *p*.

THE COROLLA.

The leaves of which the corolla consists, or *petals*, are, as a rule, much more delicate than those of the calyx, and are usually coloured, *i.e.* white or some bright colour in contradistinction to green. The colour of the corolla is, however, of subordinate importance, and is often variable in the same plant. The corolla of *Pulmonaria*, for example, is red when it first opens, and afterwards becomes violet [that of *Cobœa scandens* changes gradually from pale-green to purple], while that of *Hibiscus abelmoschus* is white in the morning, pale red by mid-day, and rose-red in the evening.[1]

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[1] [In many species also the colour varies in different individuals : thus the corolla of *Campanula rotundifolia*, usually blue, is occasionally white ; that of *Erica tetralix*, usually rose-coloured, is also occasionally white ; while that of *Polygala vulgaris* is indifferently white, blue, or rose-coloured. — Ed.]

It is unusual for the corolla to be green; in the grape-vine it is yellowish green. Certain plants, however, which have normally a bright-coloured corolla, produce occasionally a green one, as occurs in *Hydrangea* and *Hesperis*.

The corolla is *gamopetalous* or *sympetalous* [less correctly 'monopetalous'], when the petals are more or less coherent; *apopetalous* or *eleutheropetalous* [less correctly 'polypetalous'], when they are perfectly distinct; *regular* when they are all alike; *irregular* when one or more differs from the rest in size or form; but in the latter case the corolla is always *symmetrical* (see foot-note, p. 124).

The principal forms of the gamopetalous corolla are *globose* as in *Erica tetralix* (Fig. 240); *urceolate* or urn-shaped as in the bilberry (Fig. 241); *campanulate* or bell-shaped as in *Campanula* (Fig. 242); *infundibuliform* or funnel-shaped as in *Convolvulus arvensis* (Fig. 243); *tubular* as in the 'florets of the disc' of many Compositæ (Fig. 244); *rotate* as in the borage (Fig. 245); *hypocrateriform* or salver-shaped as in the jasmine (Fig. 247); *ligulate* or strap-shaped as in the 'florets of the ray' of many Compositæ (Fig. 246); *bilabiate* as in most Labiatæ (Fig.

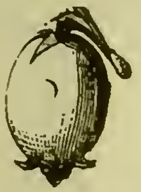
FIG. 240.—Globose corolla of *Erica tetralix* (magnified).

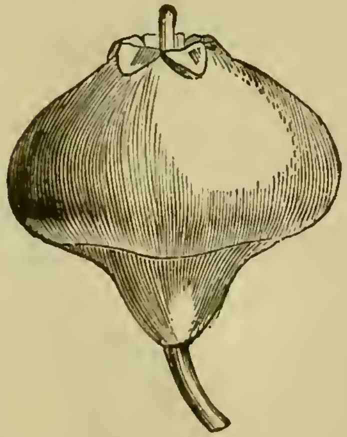
FIG. 241.—Urceolate corolla of *Vaccinium Myrtillus* (magnified).

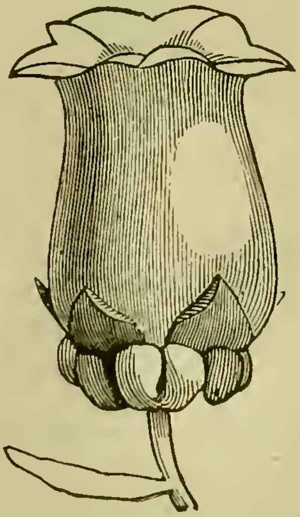
FIG. 242.—Campanulate corolla of the Canterbury bell.

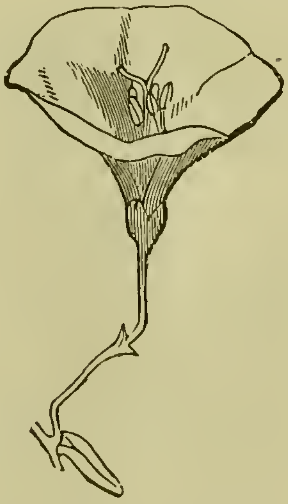
FIG. 243.—Infundibuliform corolla of *Convolvulus arvensis*.

248), where the corolla is divided into an upper and a lower lip, the former having two and the latter three teeth [representing the five petals]. When the two lips are widely separated, as in the figure, the corolla is said to be *ringent*; while, if the mouth is closed by a cushion-like formation on the underlip, called the *palate*, as in *Antirrhinum* (Fig. 249), the corolla is said to be *personate*. [The corolla, like the calyx, may be *spurred*, as

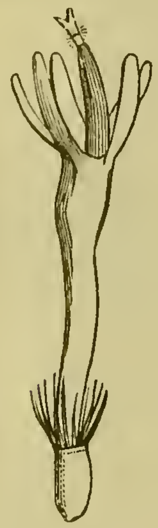

Fig. 244.—Tubular corolla from the disc of the capitulum of *Centaurea Cyanus*.

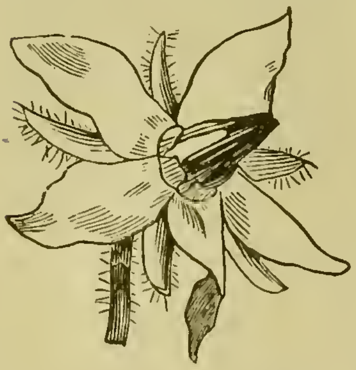

Fig. 245.—Rotate corolla of the borage, *Borrago officinalis* (magnified).

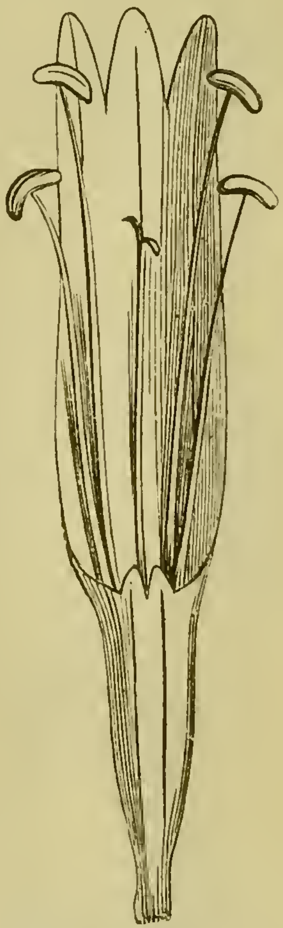

Fig. 246.—Ligulate corolla of *Globularia Alypum* (magnified).

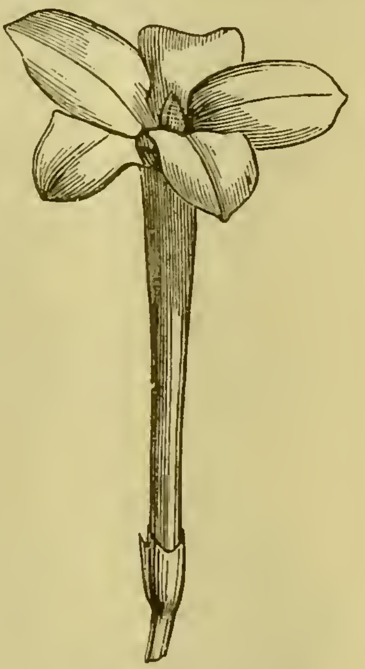

Fig. 247.—Hypocrateriform corolla of the jasmine (magnified).

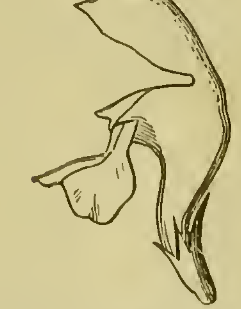

Fig 248.—Bilabiate ringent corolla of *Lamium album*.

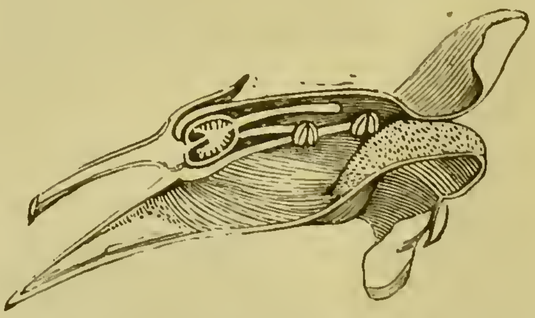

Fig. 249.—Bilabiate personate corolla of *Antirrhinum majus*.

in *Viola* and many orchises, or *hooded*, as in the monkshood].

The form of the apopetalous, like that of the gamopetalous corolla, varies, and may be *globose*, *campanulate*, *rotate*, &c.; but the most important point to note in it is the form and the relative position and number of the petals. As respects their form, they may be *entire* as in the apple; *obcordate* as in *Æthusa cynapium*; *toothed* or *fringed* as in many Caryophyllaceæ (Fig. 250); *fimbriate* as in *Dianthus plumarius*; *bifid* as in *Lychnis diurna* (Fig. 251); *unguiculate* (Figs. 250-252), when the petals are very narrow in the lower part, which forms a claw or *unguis*, while comparatively broad in the upper part or *lamina*, &c.

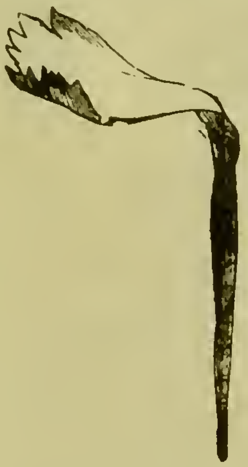

FIG. 250.—Unguiculate petal of *Dianthus*, with toothed lamina.

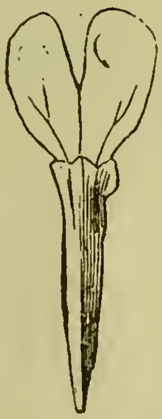

FIG. 251.—Bifid unguiculate petal of *Lychnis*, with ligule.

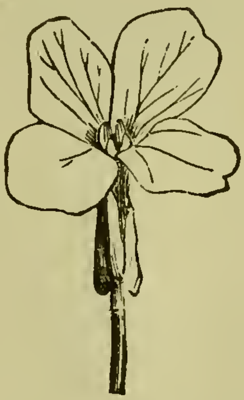

FIG. 252.—Cruciform flower of *Lunaria* with unguiculate petals.

There are several forms of the apopetalous corolla which are of especially common occurrence, and therefore worthy of note [and which are frequently characteristic of large natural groups]: *viz.* the cruciform, papilionaceous, caryophyllaceous, rosaceous, and the less common but very remarkable mitræform. In the *cruciform* corolla (Fig. 252), characteristic of the large natural order of Cruciferæ, we find four unguiculate petals arranged in the form of a cross, and alternating with the four sepals. The *papilionaceous* corolla (Fig. 253), confined to the division Papilionaceæ of the order

Leguminosæ, consists of five petals, of which one, the *standard* or *vexillum*, the uppermost, is usually the largest; at its sides are the two *wings* or *alæ*; while the lowermost part of the corolla, the *keel* or *carina*, consists of two petals often more or less united above, and usually enclosing the stamens and pistil. The *caryophyllaceous* corolla (Figs. 254, 255) consists of five petals with long ungues attached to the base of a gamosepalous [or sometimes aposepalous] calyx, [and each of the petals is often furnished with an appendage known as the *ligule*, (Fig 251) and forming together the

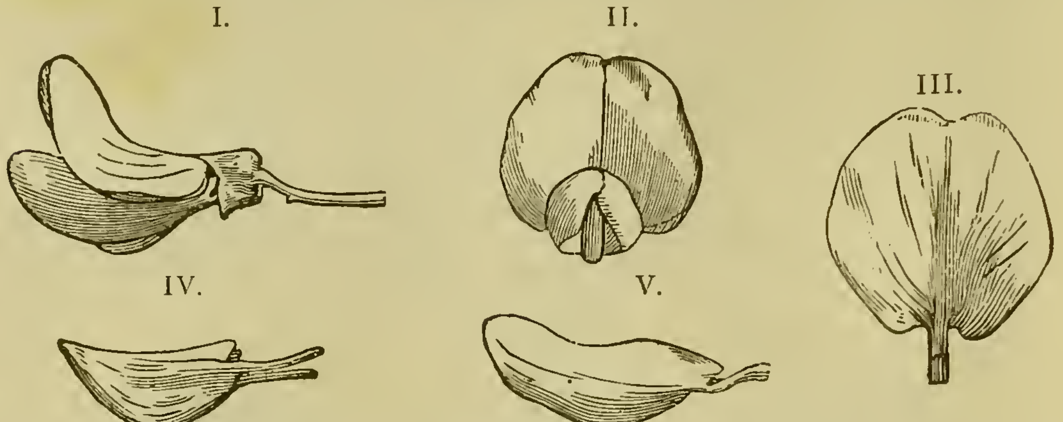

FIG. 253.—Papilionaceous corolla of laburnum: I. seen laterally; II. in front; III. standard; IV. keel; V. left wing seen from without.

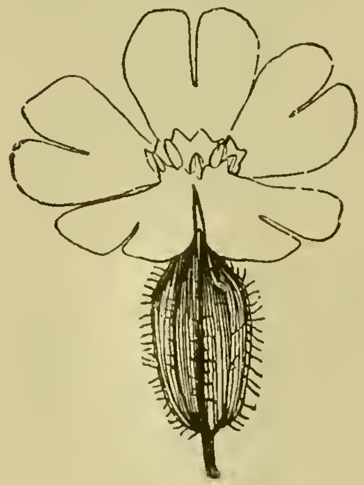

FIG. 254.—Caryophyllaceous corolla of *Lychnis vespertina*, with corona (magnified).

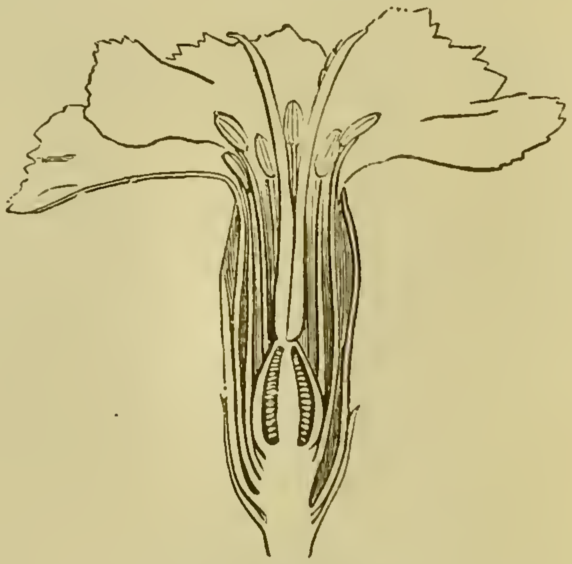

FIG. 255.—Longitudinal section through the caryophyllaceous corolla of *Dianthus* (magnified).

corona]. The *rosaceous* corolla (Fig. 256), consists of five petals which are not unguiculate, with perigynous adhesion, *i.e.* attached to that part of the urceolate or hypocrateriform calyx where the separate sepals spring from the coherent base, and is especially characteristic of a section of the order Rosaceæ. The *mitræform* corolla (Fig. 257) which occurs in the grape vine, consists of five petals which are coherent at their tips, and become detached at their base on the expansion of the flower, thus covering the inner petals of the flower like a cap.

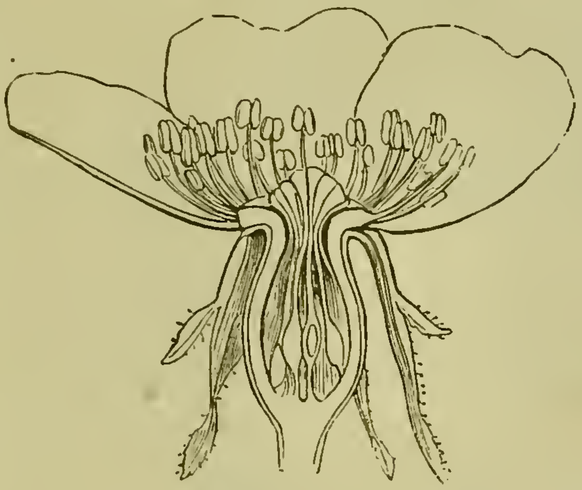

FIG. 256.—Longitudinal section through the rosaceous flower of the rose; the pistil seated in the base of the urceolate calyx.

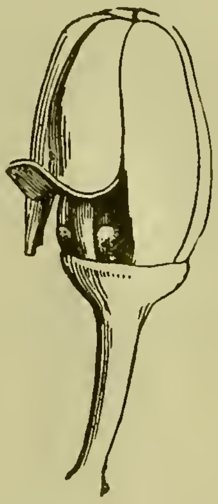

FIG. 257.—Mitræform flower of the grape-vine (magnified).

The petals usually break off when they fall by an articulation at their base, but often remain attached and withered, as in *Campanula* [when they are said to be *marcescent*]. The corolla never takes any part in the formation of the fruit, as is sometimes the case with the calyx.

THE PERIANTH.

When the Perianth (*i.e.* the two floral envelopes, the calyx and corolla) is green, as in the elm and *Rumex* (Figs. 258, 259, 260), it is said to be *sepaloid;* when bright-coloured or white, as in Orchideæ and Liliaceæ (Fig. 261), it is *petaloid*; the dry scarious perianth of grasses is *glumaceous*; that of the catkins of many forest-trees *scaly*. Similar terms may be applied to the perianth as to the calyx and corolla, with respect to the form, size, number, and arrangement of its separate parts. It may be *gamophyllous* or *symphyllous* [‘monophyllous’] on the one hand; or, on the other hand, *apophyllous* or *eleutherophyllous* [‘polyphyllous’]. It may be *deciduous*, as in orchis, or *persistent*, and may then become *accrescent* and dry as in the hazel-nut, or *succulent* as in the mulberry. In the latter cases and some others, as *Rumex* and *Hippophaë*, it takes an important part in the formation of the fruit. [Under this head come the *paleæ* and *lodicules* of grasses, and the *perigynium* of sedges.]

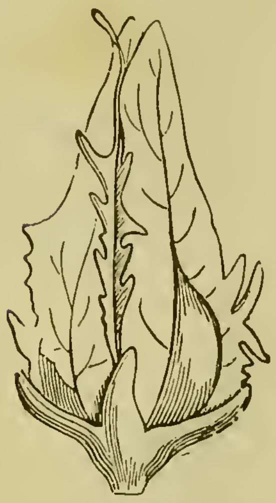

FIG. 258.—Double sepaloid perianth of *Rumex acetosa* (magnified).

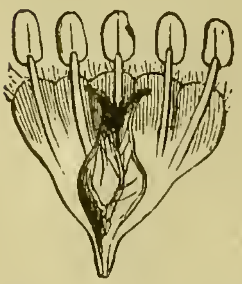

FIG. 259. — Longitudinal section through the sepaloid perianth of the elm (magnified).

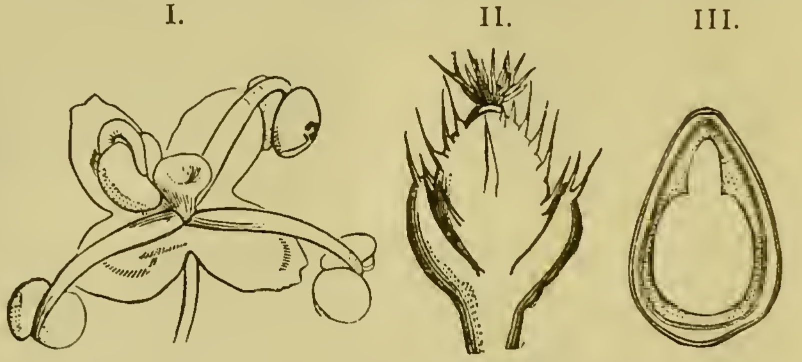

FIG. 260.—I. Staminate flower: II. pistillate flower: III. section of the fruit of the stinging-nettle, *Urtica dioica* (magnified).

SUBSIDIARY ORGANS OF THE FLOWER.

By subsidiary organs are meant appendages to the flower of various kinds which cannot be included either among the floral envelopes or the essential organs of the flower.

The *corona* or *paracorolla* is a whorl of leaf-like or filiform organs, often brightly coloured, intervening between the perianth and the stamens, and sometimes attached to the one, sometimes to the other. In the narcissus (Fig. 261) it is coherent and bell-shaped, while in the passion-flower it consists of a number of brightly coloured hairs; in *Lychnis* (Fig. 254, p. 132) it forms a small coronet at the base of the rotate lamina of the corolla; in many Borragineæ (Fig. 262) it consists of five scales [or *staminodes*] which close up the throat of the corolla-tube. In the corolla of *Lamium* it assumes the form of a circle of hairs; in the grass of Parnassus (Fig. 263) it consists of five leaves which terminate at their apex in from nine to fifteen glandular bodies. The *spur* (Figs. 264, 266), which sometimes belongs to the calyx, sometimes to the corolla, is also frequently treated as a subsidiary organ.

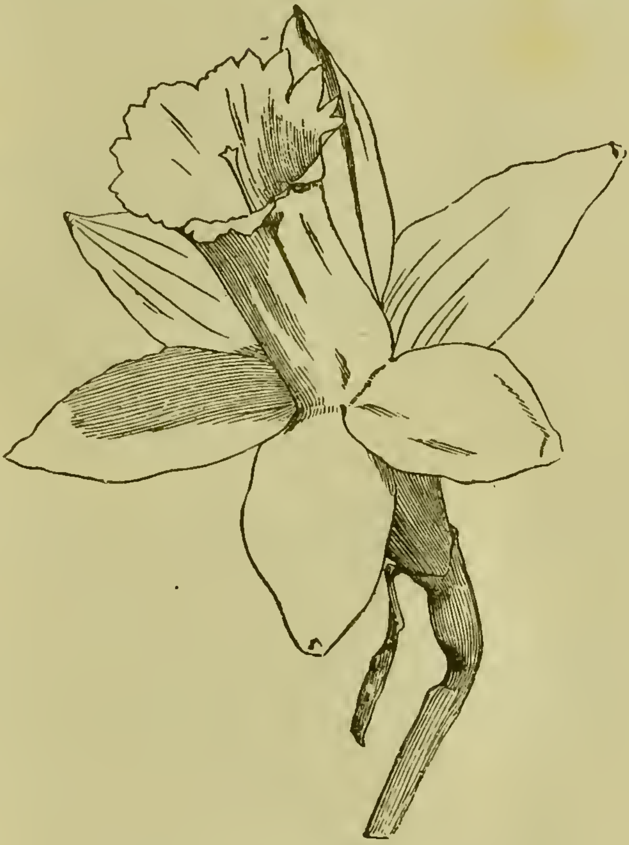
FIG. 261.—Petaloid perianth of *Narcissus*, with 6-partite limb and campanulate corona.

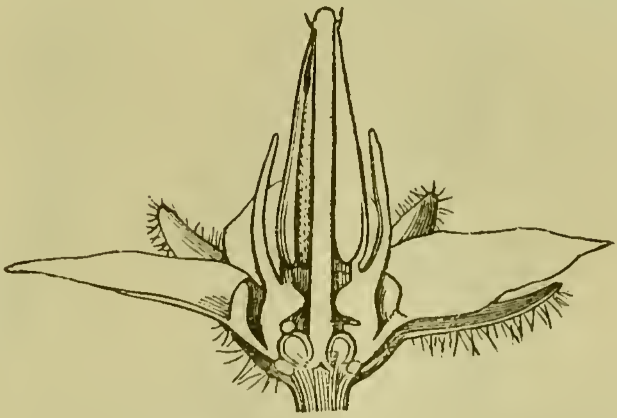
FIG. 262.—Longitudinal section through the flower of the borage; each bifid stamen bears the anther on its inner half; while the outer half forms an erect scale (magnified).

The *nectaries* must also be mentioned in this connection.

They are the part of the flower which is specially constructed for the secretion of honey, and are of great importance in attracting insects to assist in fertilisation. Instances are afforded by the shallow pits at the base of the perianth-leaves of the crown-imperial, the hollows concealed by scales at the base of the petals of *Ranunculus*, the glands between the stamens of the grape-vine (Fig. 265), [the spur of the columbine or larkspur (Fig. 266), and of many species of orchis, the appendages to two of the stamens of *Viola*, &c.]

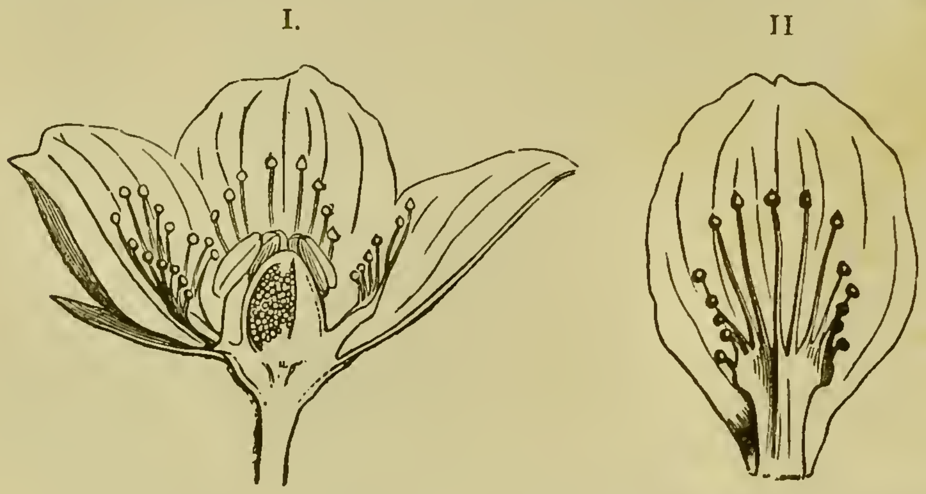

FIG. 263.—I. Longitudinal section through the flower of *Parnassia palustris*; II one of the petals (magnified); a glandular scale belonging to the corona attached to it in front.

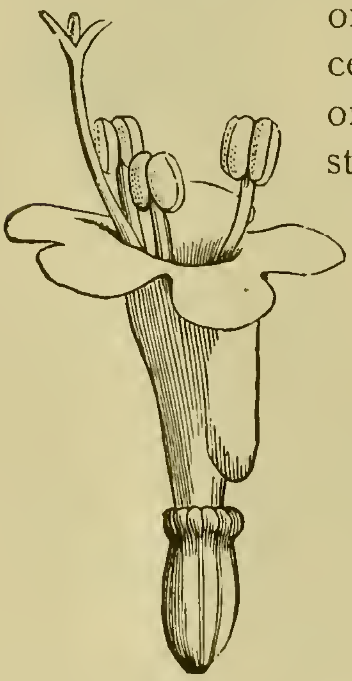

FIG. 264.—Spurred corolla of *Valeriana* (magnified).

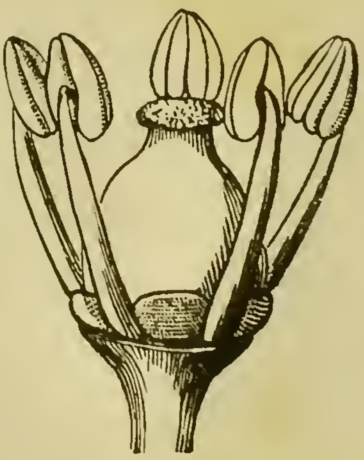

FIG. 265.—Stamens and pistil of the grape-vine, with a honey-gland (nectary) between each pair of stamens (magnified).

Lastly, we must also include under this head barren stamens or *staminodes*, filiform bodies placed either within or without the perfect stamens, but not furnished, like them, with anthers at their apex. Examples occur in [the female flowers of] the bay *Laurus nobilis*, in *Illecebrum*, *Erodium*, *Samolus*, [the borage (Fig. 262) according to some], &c.

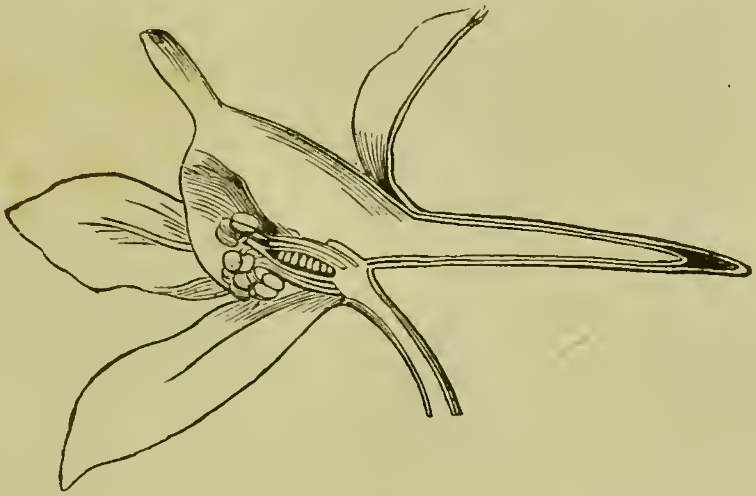

FIG. 266.—Longitudinal section of flower of larkspur, with spurred calyx and corolla (magnified).

THE ANDRŒCIUM OR STAMENS.

The Stamens consist, in their most perfect form (Fig. 267), of a longer or shorter filiform stalk, the *filament*, which bears at its apex the *anther*. The filament usually divides the anther into two halves, the *anther-lobes*. The part of the filament which is inserted between the anther-lobes is called the *connective*, and is sometimes divided into two arms, which are often greatly elongated, and are either of equal length, as in the hornbeam (Fig. 268), hazel-nut, alder, birch, and lime, or occasionally of very unequal length, as in *Salvia* (Fig. 269).

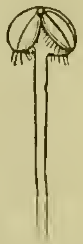

FIG. 267.—Stamen of *Lamium*, with moderately developed connective (magnified).

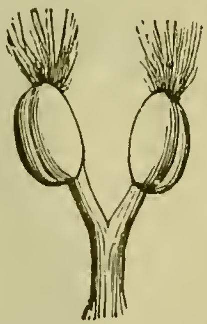

FIG. 268.—Stamen of hornbeam, *Carpinus Betulus*, with branching connective (magnified).

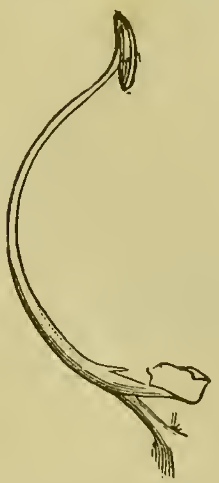

FIG. 269.—Stamen of *Salvia,* with connective branching into two arms of very unequal length; the right-hand arm bearing an abortive anther (magnified).

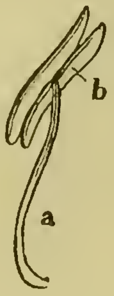

FIG. 270.—Stamen of wheat, with versatile anther *b* lightly fixed at the extremity of the filament *a* (magnified).

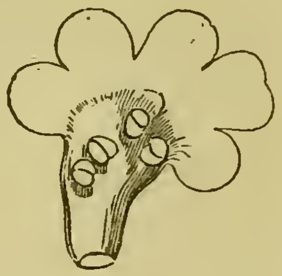

FIG. 271.—Section of corolla of *Verbena,* with sessile epipetalous anthers (magnified).

The connective usually ends with the anther-lobes, and these latter are then placed at the extremity of the filament; or less often, it grows beyond the anther, as in *Paris quadrifolia,* where the anther appears to be attached to the middle of the stamen, [or the violet, where it forms the orange tip to the stamens]. Since the essential part of the stamen is the *pollen,* which is developed within the anther, the filament may be entirely wanting, as in Orchideæ, *Verbena* (Fig. 271), [and *Viola*], when the anther is said to be *sessile.* In the Grasses (Fig. 270), the anther is fixed transversely to the filament.

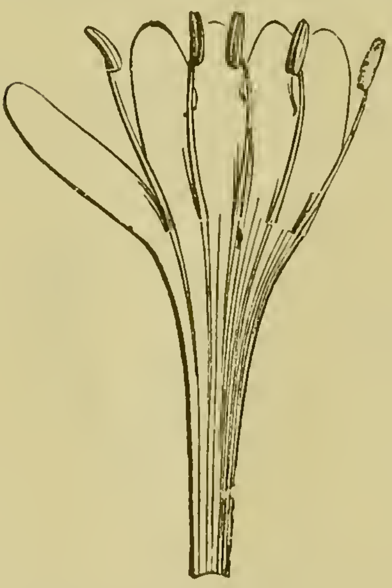

FIG. 272.—Section of corolla of honeysuckle, with epipetalous stamens.

Of great importance in connection with classification are the mode of attachment and number of the stamens, as well as the relative lengths of the filaments. For example, with but few exceptions, all Labiatæ [Scrophulariaceæ, Verbenaceæ, Gesneraceæ, Acanthaceæ, and Bignoniaceæ] have two short and two long [*didynamous*] stamens (Figs. 271, 273); all Cruciferæ (Fig. 274) two short and four long [*tetradynamous*]. It must also be noticed whether all the filaments are distinct to their base or not. Sometimes the whole of the filaments are united into a tube or sheath [*monadelphous*], as in Malvaceæ (Fig. 275) and many Leguminosæ; in other cases into two bundles [*diadelphous*], as in many Leguminosæ (Fig. 276); or into a larger number [*polyadelphous*], as in the orange (Fig. 277) and *Hypericum.* Again, when the filaments are perfectly

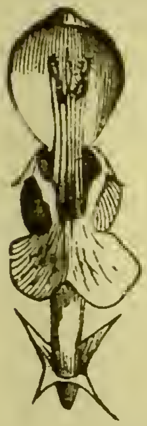

FIG. 273.—Flower of *Lamium*, with didynamous stamens.

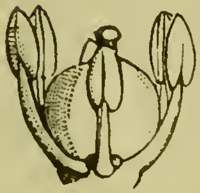

FIG. 274.—Pistil and tetradynamous stamens of *Cochlearia*.

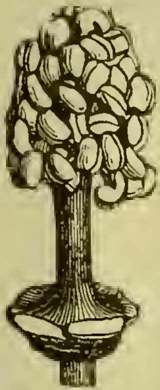

FIG. 275. — Monadelphous stamens of *Malva*.

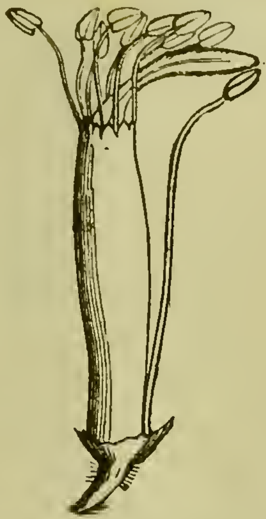

FIG. 276. - Diadelphous stamens of *Lathyrus*; nine filaments united into a sheath at the base; one free.

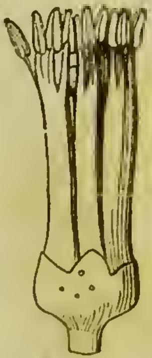

FIG. 277 — Polyadelphous stamens of orange (magnified).

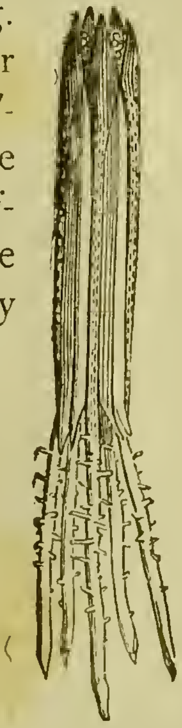

FIG. 278 —Syngenesious anthers of thistle: the filament free (magnified).

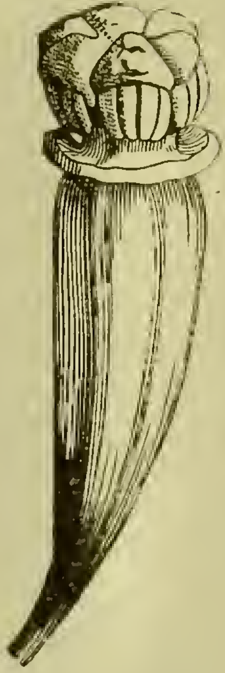

FIG. 279.—Stamens of *Aristolochia* sessile upon the stigma (magnified).

distinct, the anthers may be coherent or united by their margins [*syngenesious*], as occurs in Compositæ (Fig. 278). Occasionally, the anthers are sessile upon the stigma [*gynandrous*], as in Orchideæ (Fig. 279).[1]

The *pollen* is formed in the cavities of the anther-lobes, which are termed *loculi*, and are most often two, more rarely one or four in number, the anther being then termed *unilocular*, *bilocular*, or *quadrilocular*. In most plants it consists of minute *pollen-grains*, entirely distinct from one another; less often, as in Orchideæ and Asclepiadeæ (Fig.

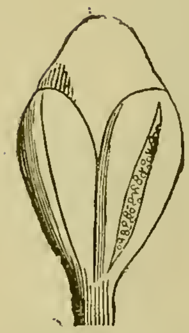

FIG. 280.—Stamen of *Pinus sylvestris* with longitudinal dehiscence (magnified).

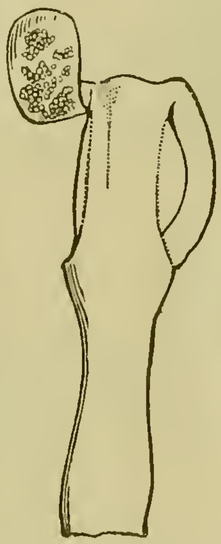

FIG. 281.—Stamen of barberry, the anther opening by recurved valves (magnified).

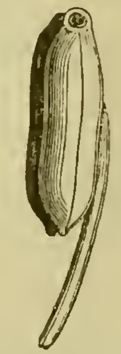

FIG. 282.—Stamen of *Rhododendron*, each anther-lobe opening by a pore.

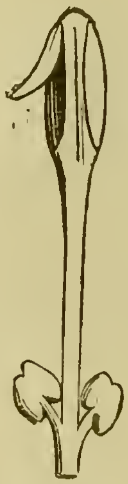

FIG. 283.—Stamen of bay, *Laurus nobilis*, with two glands at the base of the filament, the anther opening by recurved valves.

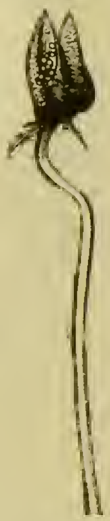

FIG. 284.—Stamen of *Erica*, the anther opening by pores and bearing two appendages at its base (magnified).

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[1] [As respects their adhesion or mode of attachment, stamens are *hypogynous* when growing directly from the receptacle beneath the ovary (*Ranunculus*, Cruciferæ); *perigynous* when springing from the calyx (*Rosa*, *Fuchsia*); *epipetalous* from the corolla (*Primula*, *Lamium*); *epigynous* when attached to the upper part of the pistil (Umbelliferæ, *Rubia*). With reference to the mode of attachment of the anther to the filament, the former is *basifixed* or *innate* when attached by its base (heath, tulip); *dorsifixed* or *adnate* when attached by its back (onion, myrtle); *versatile*, when, in the latter case, the attachment of the anther to the filament is very slender, as in most Grasses (Fig. 270).—ED.]

355, p. 183), they are united into a waxy mass [or *pollinium*]. On the maturity of the anthers, they burst open or dehisce in a manner which is well defined beforehand. This usually takes place by means of a longitudinal fissure in each anther-lobe (Fig. 280), *longitudinal dehiscence*, most often on the inner side of the anther, facing the pistil, *introrse*, less frequently on the outer side facing the corolla, *extrorse*, as in Irideæ, [or precisely at the side, *lateral*, as in *Ranunculus*]. Less common modes of opening are the *dehiscence by recurved valves*, [when the side of the anther-lobe is turned back as on a hinge], as in *Berberis* and *Laurus* (Figs. 281, 283); and *by pores* (Figs. 282, 284), as in the Ericaceæ, *Polygala*, *Solanum*, &c.; [still less frequent is the *transverse dehiscence*, as in *Alchemilla*.] In some cases, appendages of a peculiar structure, of a leaf-like or glandular nature, are attached to the filaments, as in *Viola*, the borage, onion, bay, &c. (Fig. 283), or to the anther, as in many Ericaceæ (Figs. 284, 285). [Between the corolla and the stamens is sometimes an elevated ring known as the *disc*.]

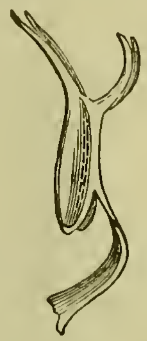
FIG. 285.—Stamen of *Vaccinium*, with appendages at the base of the anther.

The foliar nature of the stamens is especially well seen from the fact that very frequently—especially in many so-called *double flowers*—the stamens are converted into petals; or occasionally stamens are developed instead of petals, as is often seen in the shepherd's purse. It is also not uncommon to find in the same flower a gradual transition between the stamens and petals, as occurs normally in Nymphæaceæ and *Rosa centifolia* (Fig. 286).

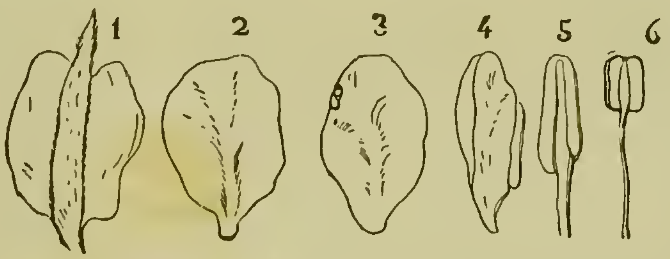

FIG. 286.—Stages of transition between the petals and stamens of *Rosa centifolia*.

THE GYNÆCEUM OR PISTIL.

The Pistil consists, in its most perfect form (Fig. 287), of three parts:—the lowermost swollen part, a hollow cavity containing the ovules, is the *ovary*; the middle slenderer part is the *style*; and the uppermost usually thicker part is the *stigma*.

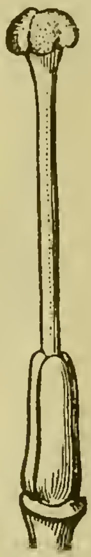

FIG. 287.—Pistil of lily, with ovary, style, and stigma.

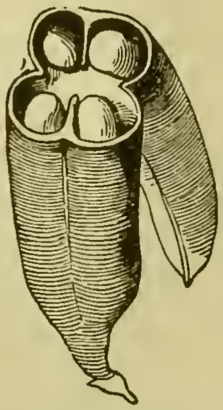

FIG. 288.—Legume of *Astragalus*, partly cut through.

The pistil is composed of one or more organs of a foliar nature, the *carpels*; and their number is almost always indicated by the seams or sutures on the outside of the ovary. A knowledge may thus be obtained of the constitution of the fruit, which is often characteristic of whole families of plants. Thus, from the structure of the legume (Fig. 288) it may be concluded that it consists of a single carpel; while in the same manner it is seen that the capsule of *Colchicum* (Fig. 289) is composed of three carpels.

If a suture faces the centre of the flower, it is called the *ventral suture*; while one facing the perianth is called the *dorsal suture*. It is common for the carpels of which a pistil consists to be coherent at the base while distinct in the upper part, and we have then a single ovary with several styles or stigmas, as in the apple. As a general rule the style and stigma are a prolongation of the mid-rib of the carpel, although exceptions occur, as in the Papaveraceæ. Pistils which consist of a single carpel are said to be *monocarpellary* [as in Leguminosæ and Primulaceæ]; when of two or more carpels *bicarpellary*, *tricarpellary*, *polycarpellary*, &c. [If the carpels of which a pistil is composed are more or less completely welded together, it is *syncarpous* (Figs. 313, 320, 323, 326); if quite distinct, it is *apocarpous* (Figs. 314, 315).]

The *style* is not an essential part of the pistil, and is therefore not unfrequently wanting, as in the poppy (Fig. 294). When present it is usually placed at the summit of the ovary, *terminal*, but occasionally springs from its base, and is then *lateral* or *basilar*, as in the strawberry and *Bromus* (Figs. 290, 292).

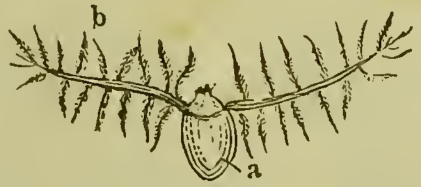

FIG. 292.—Pistil of *Bromus* ; *a* ovary, *b* plumose stigma (magnified).

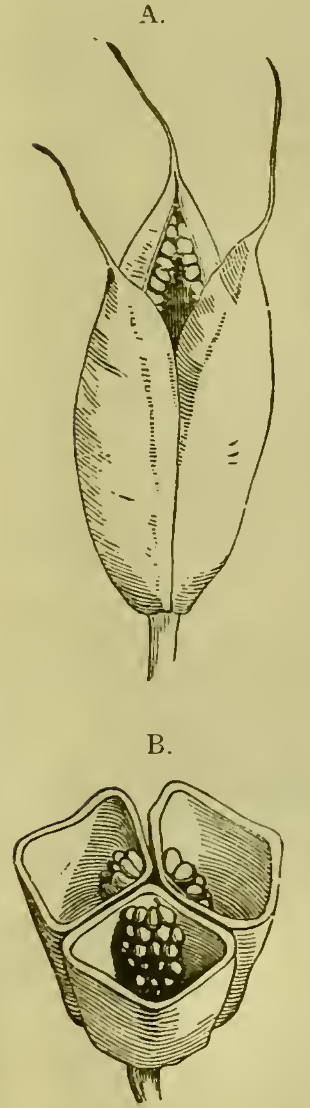

FIG. 289. — Capsule of *Colchicum* ; A at the moment of dehiscence ; B transverse section.

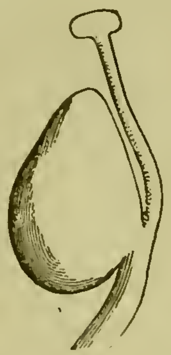

FIG. 290. — Basilar style of *Alchemilla* (magnified).

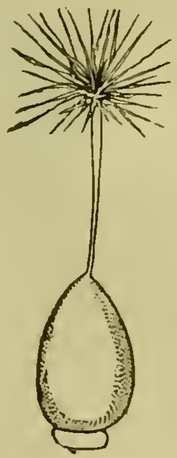

FIG. 291.—Pistil of *Parietaria*, with penicillate stigma (magnified).

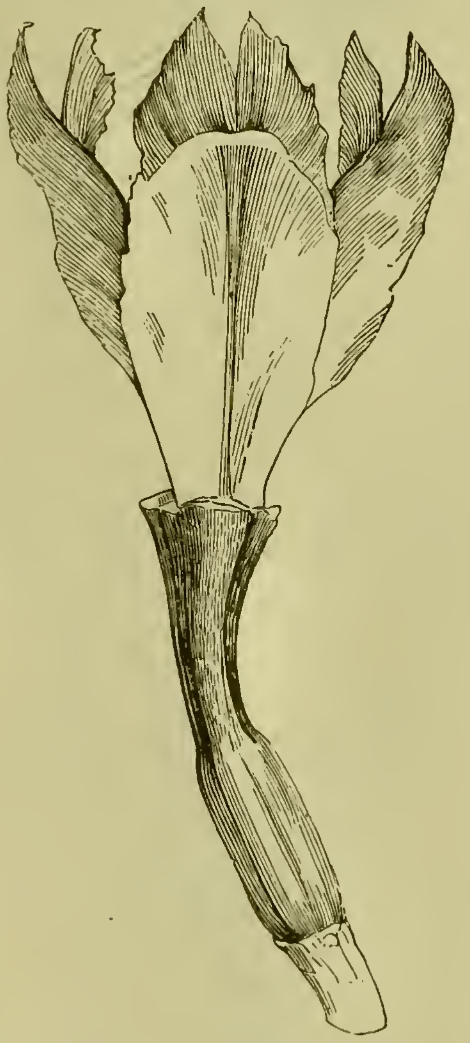

FIG. 293.—Petaloid stigmas of *Iris*.

The purpose of the *stigma* is to serve for the detention of the pollen-grains ; and it is therefore universally present, though it varies greatly in form. It may be *capitate* or button-shaped (Fig. 287); *penicillate* or consisting of long slender arms (Fig. 291); *plumose* or *feathery* (Fig. 292); *petaloid* as in *Iris* (Fig. 293); *peltate* or shield-like as in the poppy (Fig. 294); *filiform* as in *Luzula*; *papillose* or covered with papillæ (Fig. 295), &c.

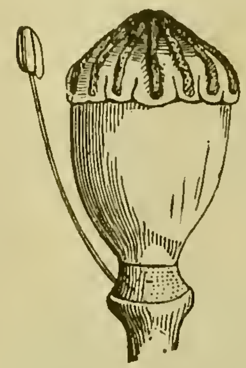
FIG. 294.—Peltate stigma of poppy, with hypogynous stamen.

The interior of the ovary is occupied by one or more cavities or *loculi*, [the walls which separate them being the *septa* or dissepiments]. Thus the ovary of Leguminosæ and Primulaceæ is *unilocular* (Figs. 296, 298); that of Scrophulariaceæ and most Cruciferæ *bilocular* (Fig. 297); that of the apple *quinquelocular*, &c.

Within the loculi of the ovary are the *ovules*, the bodies which ultimately develope into the seeds. They are fixed to certain parts of the wall of the ovary termed the *placentæ*; and are either *sessile* (Fig. 298), or are attached to the end of a stalk or *funiculus*

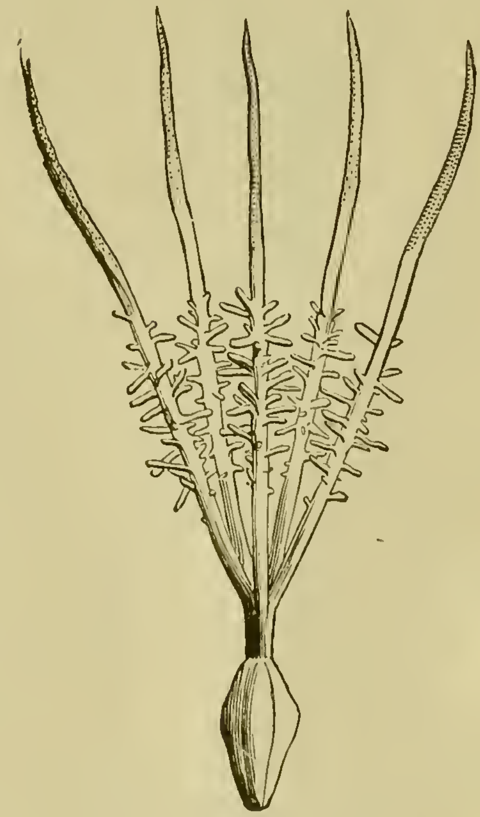
FIG. 295.—Papillose stigma of *Statice* (magnified).

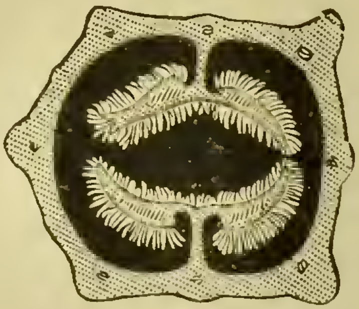
FIG. 296.—Unilocular ovary of *Pentaraphia* (Gesneraceæ), with parietal placentæ (magnified).

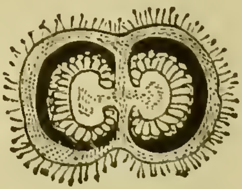
FIG. 297.—Bilocular ovary of *Antirrhinum*, with axile placentæ.

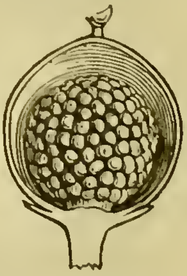
FIG. 298.—Unilocular ovary of *Hottonia*, with free central placenta.

(Fig. 299). In a few cases the whole of the interior wall of the ovary or of the loculi serves as a placenta, as in the poppy ; or a single placenta stands in the centre of the unilocular ovary like a column, as in Primulaceæ [when the placentation is *free central*] ; more often certain portions of the inner walls of the loculi, corresponding in number to the carpels and often projecting, bear the ovules, and are then called *parietal* placentæ [as in *Viola* or *Ribes*] ; [or the ovules are attached to the common axis of all the loculi of a multilocular ovary, as in the apple or *Iris*, when the placentation is *axile.*] As respects the mode of attachment of the ovules to the loculus, they may be either *erect*, [*lateral*], or *pendulous*.

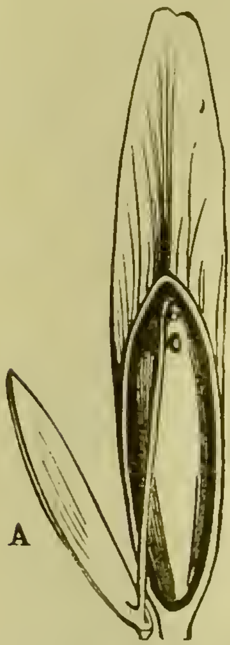

FIG. 299.—Ovary of the ash ; the single seed attached to a long funiculus, and still enclosed in the ovary ; A, a detached piece of the wall of the ovary.

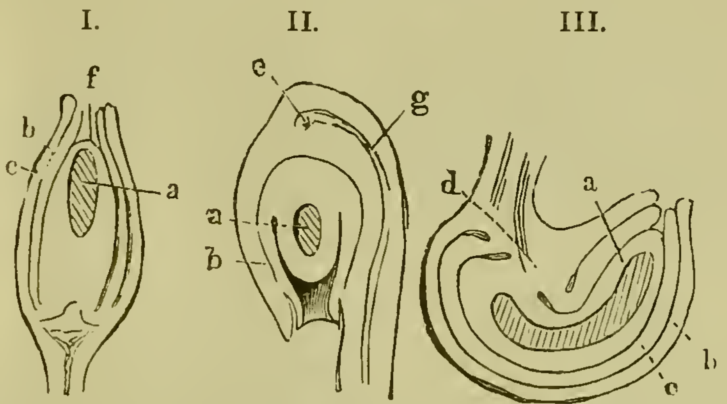

FIG. 300.—I. Orthotropous ; II. anatropous ; III. campylotropous ovule ; *a* nucellus with the embryo-sac coloured dark ; *b* primine ; *c* secundine ; *d e* chalaza ; *f* micropyle; *g* raphe (represented diagrammatically).

If a section is made through the longer axis of an ovule, and the surfaces examined under a magnifying-glass, it is seen that the ovule consists of a [cellular] *nucellus* (Fig. 300 *a*) enclosed in a single or more usually in a double coat or *integument* (*b*, *c*), [the outer coat being designated the *primine*, the inner coat the *secundine*]. At the apex of the ovule is a small orifice through the integuments, called the *micropyle* or *foramen* ; [and in the interior of the nucellus is a large cell called the *embryo-sac*]. With regard to their form, ovules may be classified into three kinds—the *ortho-*

tropous (or atropous), in which the ovule and nucellus are straight, and the micropyle is exactly opposite the base of the ovule (Fig. 300, I.); *campylotropous*, in which the nucellus is curved so as to bring the micropyle near the base (Fig. 300, III.) ; and *anatropous*, where the ovule is itself inverted so as also to bring the micropyle near the base, but the nucellus remains straight (Fig. 300, II.). [The last is by far the most common form of the ovule ; illustrations of the first are afforded by Polygonaceæ; of the second by Caryophyllaceæ. The point where the nucellus and integuments coalesce is called the *chalaza* ; in the anatropous ovule this is at the opposite end to the *hilum* (the part of the ovule which is attached to the placenta), and is connected with it by a fibrovascular bundle, *g*, called the *raphe*].

THE FRUIT.

The fruit is the result of the development of the ovary ; but is usually formed only after the fertilisation of the ovules, and, when mature, encloses the seeds which have developed from the ovules. Hence the product of an inflorescence, such as a bunch of grapes, is not properly a fruit, but rather a group of fruits, each separate berry or grape being a distinct fruit. Collections of fruits of this kind, resulting from the maturity of inflorescences, are termed *syncarps* or multiple fruits, and may be classified under racemes, spikes, umbels, &c. It is also not uncommon for other parts of the flower besides the ovary to unite with it in the formation of the so-called 'fruit' ; and such similitudes of true fruits are called *pseudocarps*. The rose-hip, for example, is a pseudocarp, because it results partly from the development of the calyx-tube, each little 'stone' which is enclosed in it being a mature ovary. The strawberry (Fig. 301) is also of this character, the succulent sapid mass being a portion of the receptacle which has become fleshy, while the small so-called 'seeds' which are imbedded in its

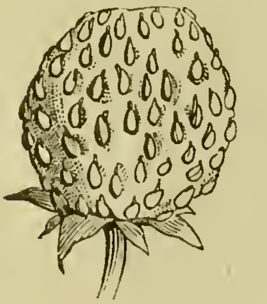
FIG. 301. — Pseudocarp of the strawberry.

surface are the actual fruits. The apple again is a pseudocarp [here termed a *pome*], the flesh being mainly developed out of the calyx-tube,[1] which even when in flower is adherent to the ovary. In the spinach the perianth, in the oat the glumes, take part in the formation of the pseudocarp. Pseudocarps are sometimes formed not of simple, but of multiple fruits. Thus the mulberry (Fig. 302) is a *pseudo-syncarp*, resulting from the coalescence of the bracts with the perianth; and the same is the case also with the pineapple, the fig (Fig. 215, p. 118), the breadfruit, &c.

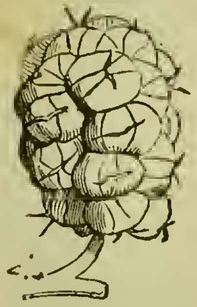

FIG. 302.—Multiple pseudocarp of the mulberry.

Additional examples of the participation of the calyx or of the perianth in the production of the fruit have already been adduced (pp. 126, 134). Mention has yet to be made of the husk in which the hazelnut is seated, this being the greatly enlarged perianth; while on the other hand the cup or *cupule* of the oak, beech, and sweet chestnut arises from a cup-shaped organ which is formed only after fertilisation between the ovary and the perianth, and produces leaves on its outer margin (Fig. 303).

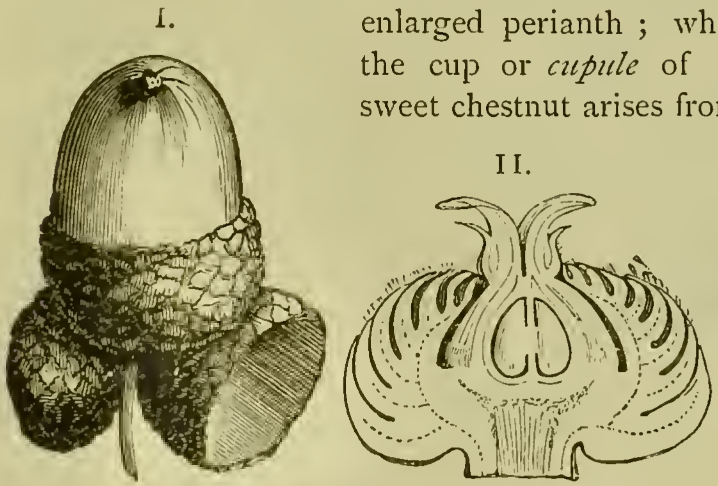

FIG. 303.—I. Acorn of *Quercus sessiliflora* with two empty cupules; II. longitudinal section through the fertilised pistillate flower, with the cupule in an early state.

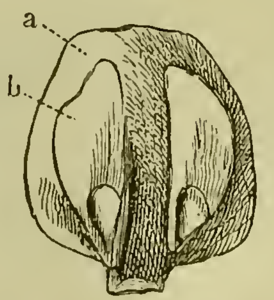

FIG. 304.—*a* Scale of the larch-cone seen from above; *b* one of its two winged naked seeds, *i.e.* not enclosed in an ovary.

Special reference must be made to the Coniferæ, in which there is no ovary, but only naked ovules (Fig. 304), and which therefore cannot form a true fruit. The class to which they belong are hence termed *Gymnosperms* or naked seeded.

---

[1] [Or, as some consider, of the receptacle.—ED.]

In observing a fruit, care must be taken to distinguish the wall of the cavity which encloses the seeds, or *pericarp*, which may consist of several layers of a membranous, fleshy, or stony consistence (Fig. 305). The nature of the outermost layer or *epicarp* determines whether the fruit has a smooth appearance like the cherry, rough like the peach, or spiny like the thorn-apple (Fig. 310, p. 150). The middle layer or *mesocarp* is often fleshy or succulent, and is then called the flesh or *sarcocarp* [as in the peach or cherry]. The innermost layer or *endocarp* is often very hard, and forms the stone or *putamen* of stone-fruit ; it encloses the cavities of the fruit which correspond to the loculi of the ovary, and are still termed *loculi*. The number of these loculi generally corresponds to the number in the ovary, although one or more not unfrequently disappear in the course of development. Such a disappearance or abortion is the rule in the lime, in which the ovary is originally quinquelocular, in *Isatis* where it is bilocular, [and the oak where it is trilocular], while in all these cases the fruit is ultimately unilocular.

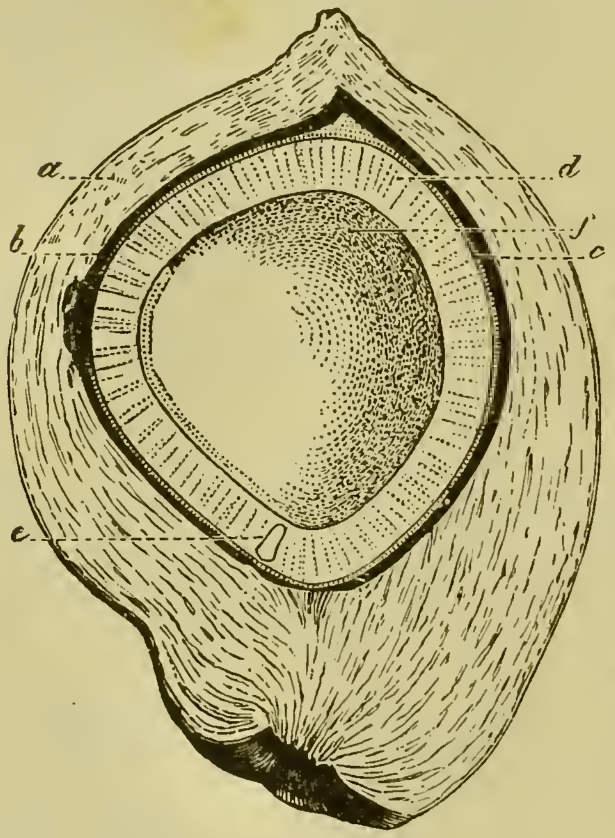

Fig. 305.—Longitudinal section of cocoa-nut : *a* epicarp ; *b* endocarp ; *c* testa : *d* endosperm or albumen ; *e* embryo ; *f* cavity in the endosperm which contains the milk.

Fruits may be divided into two primary classes, *dehiscent* and *indehiscent* ; to the former belong the capsule and schizocarp ; to the latter the drupe, berry, and achene.

The *capsule* bursts or dehisces when ripe, and allows the seeds to fall out. If this splitting takes place only at the apex (Fig. 306), it is said to dehisce by *teeth*, as in most Caryophyllaceæ; the capsule of *Lychnis diurna*, for example, dehisces by ten, that of *Githago segetum* by five teeth. If the dehiscence takes place right to the base of the capsule it is said to be valvular or *sutural*, the number of valves depending on that of the placentæ or carpels. It is *loculicidal* (Fig. 307) when the walls of the loculi split open so that the septa remain attached to the valves, as in *Iris* or the lilac; *septicidal* (Fig. 308), when, as in *Colchicum*, the septa themselves split down the middle and fall off with the valves; *septifragal* (Figs. 309, 310), when the valves separate from the septa and fall off alone, as in *Datura*. More rarely the upper part of the capsule becomes detached in the form

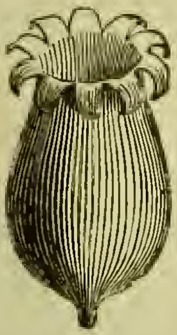

FIG. 306.—Capsule of *Primula* dehiscing by ten teeth.

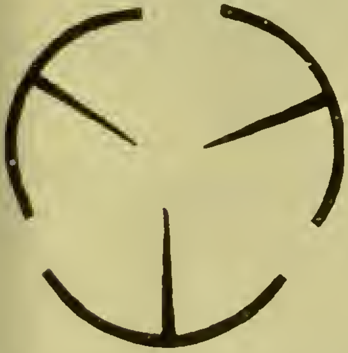

FIG. 307.—Diagram of a loculicidal capsule.

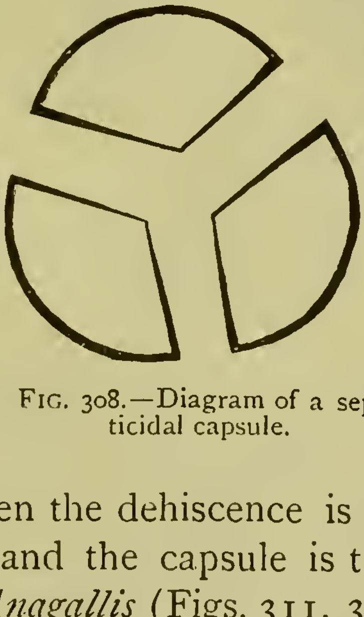

FIG. 308.—Diagram of a septicidal capsule.

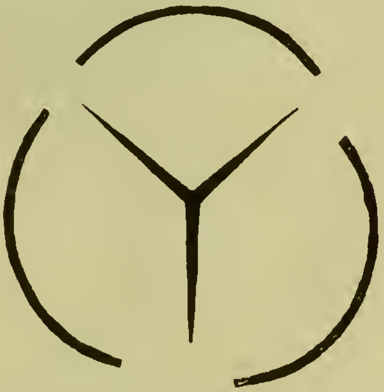

FIG. 309.—Diagram of a septifragal capsule.

of a cap or lid, when the dehiscence is said to be *transverse* or circumscissile, [and the capsule is termed a *pyxis*], as in *Hyoscyamus* and *Anagallis* (Figs. 311, 312). Some capsules again dehisce by *pores* (Fig. 313), as the poppy, *Campanula*, &c. [when they are termed *pore-capsules*]. Capsules may be unilocular or multilocular, superior or inferior, and may have free central, axile, or parietal placentation.

Follicle (Figs. 314, 315) is the term given to a unilocular capsule which dehisces only by the ventral suture. The capsule of Leguminosæ [which is always unilocular and monocarpellary, and dehisces by both ventral and dorsal sutures], is called a *legume* (Fig. 316), that of Cruciferæ [which is always bicarpellary, the seeds remaining attached

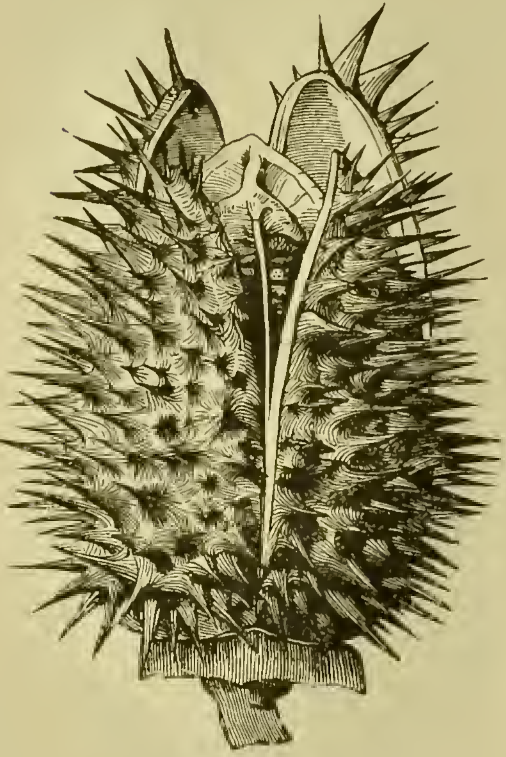

Fig. 310.—Septifragal capsule of *Datura*.

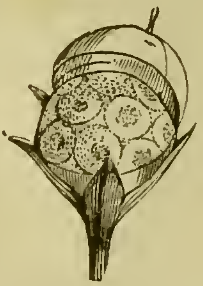

Fig. 311.—Capsule or pyxis of *Anagallis*, with circumscissile dehiscence.

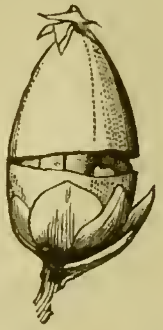

Fig. 312.—Capsule or pyxis of *Plantago*, with circumscissile dehiscence.

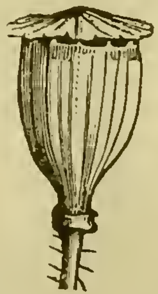

Fig. 313.—Capsule of poppy dehiscing by pores beneath the peltate stigma.

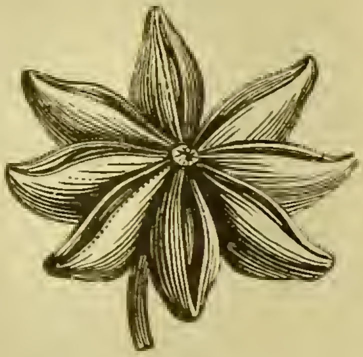

Fig. 314.—Fruit of *Illicium* or star-anise, consisting of a number of follicles.

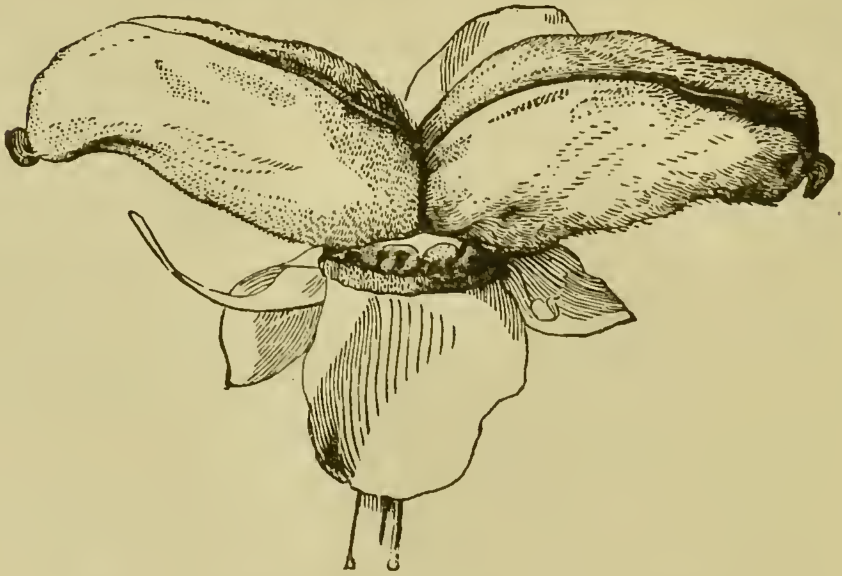

Fig. 315.—Fruit of peony, consisting of two follicles.

to a false septum or *replum*] a *siliqua* [when much longer than broad, when only about as long as broad, a *silicula* (Fig. 317)].

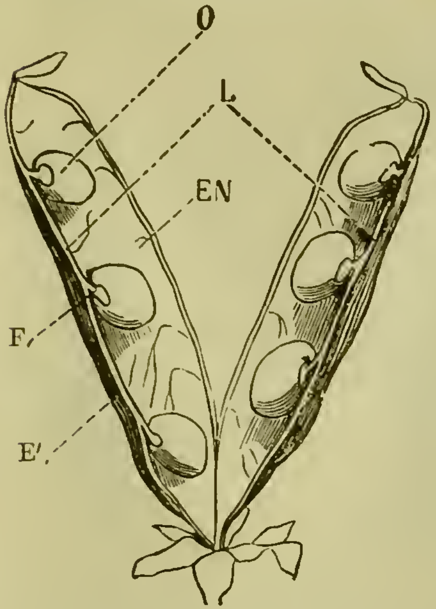

FIG. 316.—Legume of pea split lengthwise; E outer, E N inner layer of the pericarp; L placenta; F funiculus; O seed.

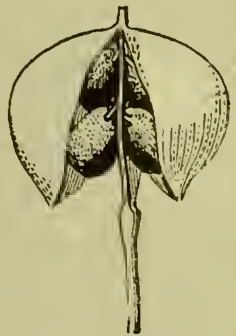

FIG. 317. — Silicula of *Cochlearia* open and showing the seeds attached to the replum.

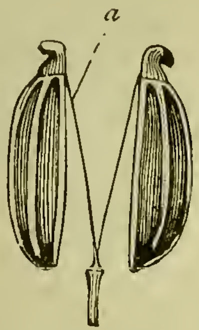

FIG. 318. — Cremocarp of the fennel; *a* carpophore.

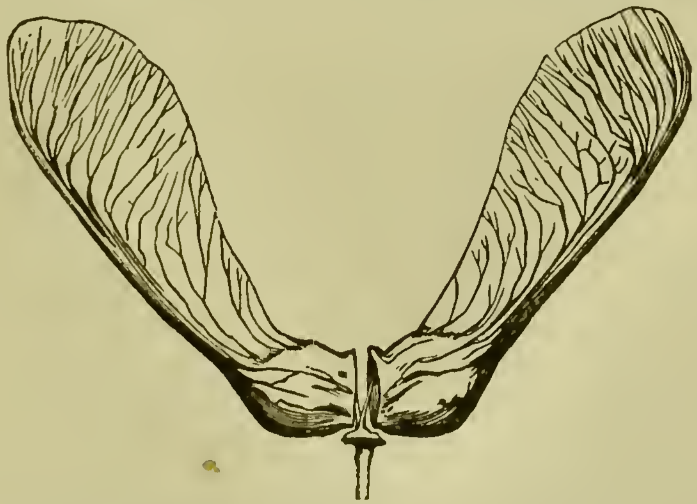

FIG. 319.—Bipartite schizocarp of the maple, consisting of two samaræ.

The *schizocarp* splits up, when ripe, into distinct pieces, called *mericarps*. These last contain usually each a single seed, and as a rule remain closed, seldom opening to allow the seeds to escape in the manner of a capsule. The splitting may be either longitudinal or transverse. In the former case the schizocarp may split into two pieces, as occurs in Umbelliferæ [where it is termed a *cremocarp*], the mericarps separating at their lower part, and remaining attached at their apex to the filiform *carpophore* (Fig. 318), or in the maple (Fig. 319); or it may divide into three as in *Euphorbia* and *Tropæolum* (Fig. 320); or into four as in Labiatæ (Fig. 321), [where they are often called *nucules*, and the entire schizocarp a *carcerulus*]; or into five as in *Geranium* (Fig. 322); or a larger number as in *Malva* (Fig. 323). A transverse splitting of the schizocarp at right angles to the axis of the flower occurs in some Leguminosæ and Cruciferæ of the suborder Lomentaceæ, where the fruit is called a *lomentum* (Fig. 324).

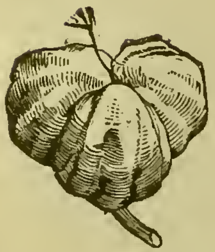

FIG. 320. — Tripartite schizocarp of *Tropæolum.*

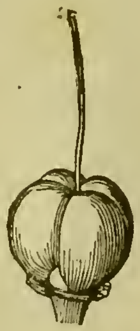

FIG. 321.—Quadripartite schizocarp (carcerulus) of *Ajuga,* consisting of four nucules.

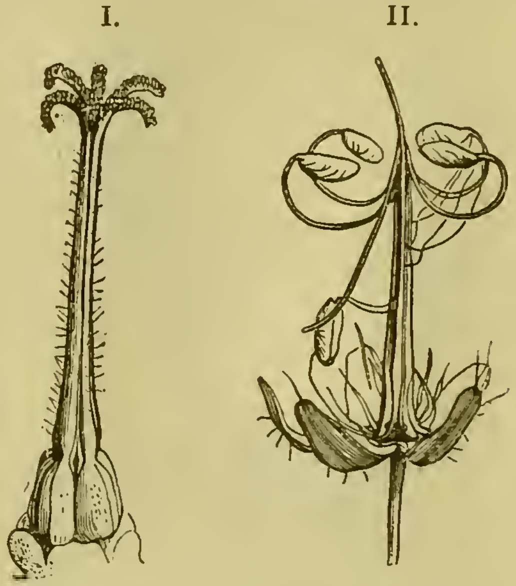

FIG. 322. — Quinquepartite schizocarp of *Geranium robertianum*; I. the immature pistil; II the mature fruit.

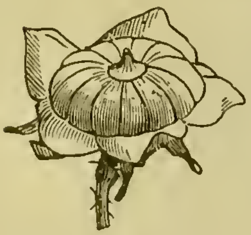

FIG. 323. — Multipartite schizocarp of *Malva.*

Passing to indehiscent fruits:—in the *drupe* or stone-fruit the various layers of which the pericarp consists develope in a different manner, the mesocarp (sarcocarp) becoming softer and more succulent, the endocarp (putamen) harder, dry and woody, and forming the stone which encloses the kernel. The consistency of the mesocarp, however, differs greatly; in the peach, plum, and cherry (Fig. 325 I.) it is very soft and succulent; in the cocoa-nut (Fig. 305, p. 148) it is fibrous;

in the almond and walnut, dry and almost leathery. The drupe usually contains a single stone, rarely more as in the medlar, when the separate sections of which it is composed are called *pyrenes* ; it is usually unilocular, as in the peach,

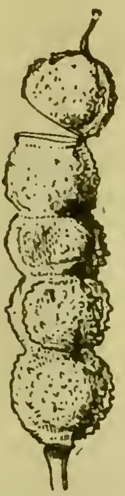

FIG. 324.—Lomentum of *Hedysarum*.

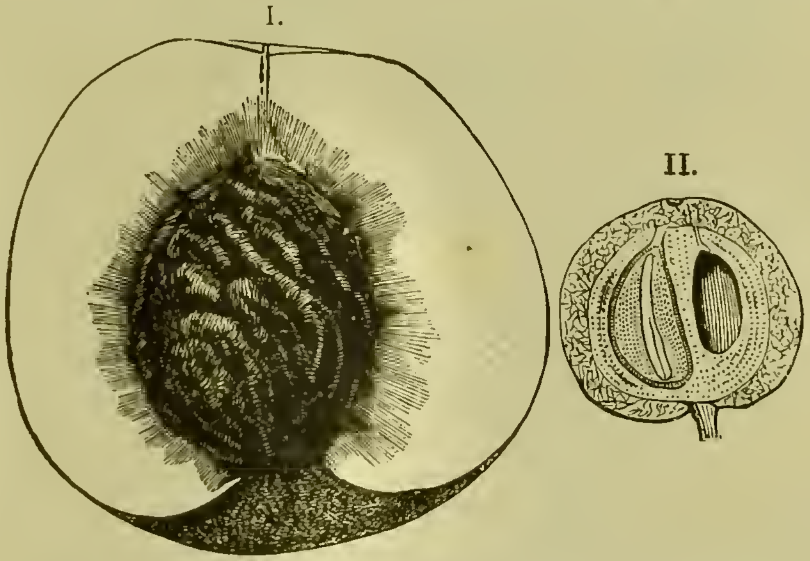

FIG. 325.—I. Longitudinal section through the unilocular drupe of the peach ; II. through the bilocular drupe of *Cornus*.

almond, and walnut, sometimes bilocular, as in the cornel (Fig. 325 II.) and coffee-berry.

In the *berry* all the layers of the pericarp are fleshy and succulent, as in the grape, currant, and gooseberry (Fig. 326) ; or the outer layers are harder, as in the citron and gourd, [the latter sometimes called a *pepo*]. The apple is a berry-like pseudocarp.

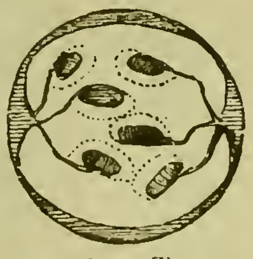

FIG. 326. — Transverse section through a gooseberry ; the firmer outer layer of the pericarp encloses the succulent flesh; the seeds lie imbedded in the latter, and are attached by long funiculi to two opposite parietal placentæ.

In the *achene* all the layers of the pericarp are dry and nearly similar. It almost invariably contains only a single seed, and is usually also from the first unilocular and with only one ovule, as in Grasses and Compositæ (Fig. 327) ; less frequently it becomes unilocular in the course of development, by the abortion of some of the ovules and the disappearance of some of the loculi, as in the oak and alder. The pseudocarp of the rose contains several achenes. The fruit of the elm, ash, maple, &c. (Fig. 319, p. 151), known as a *samara*, is an achene [or schizocarp] with membranous appendages or wings [which enable it to be carried by the wind through the air].[1]

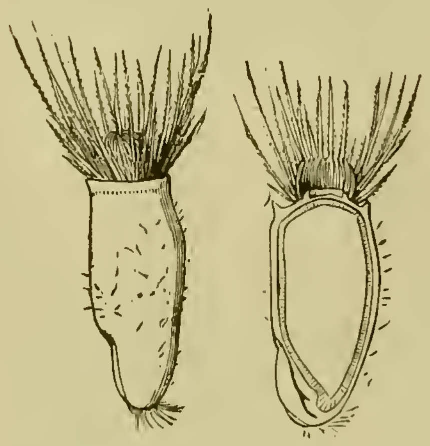

Fig. 327. — Achene or cypsela of *Centaurea Cyanus*, entire and cut through lengthwise (magnified).

THE SEED.

The seed or mature ovule is the organ by means of which the higher plants are chiefly propagated. It is connected with the placenta or part of the internal wall of the ovary to which it is attached by a more or less strongly developed stalk or *funiculus* (Fig. 326); when this is so short as to appear to be altogether absent, the seed is said to be *sessile*.

The *arillus* is an appendage springing from the point of attachment of the seed to the placenta or *hilum*, from whence it rises up and envelopes it. In the ripe seed of the willow it is split up into long silky hairs; in the nutmeg it

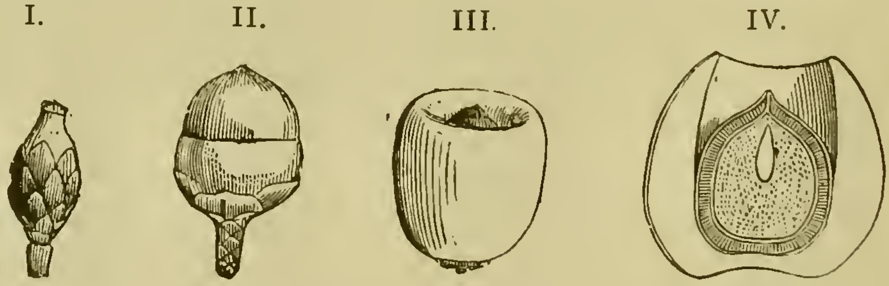

Fig. 328.—I., II., III., Development of the arillus of the yew; IV. longitudinal section through the ripe seed.

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[1] [The *nut* (Fig. 485, p. 380) and *glans* (Fig. 303, p. 147) are one-seeded achenes resulting by abortion from a trilocular ovary, in which the epicarp is more or less lignified. The *caryopsis*, characteristic of Grasses, is an achene in which the membranous pericarp adheres closely to the seed; the inferior achene of Compositæ is sometimes called a *cypsela*. The *hesperidium*, as in the orange, is a multilocular berry in which there is a remarkable development of succulent cells from the endocarp.—Ed.]

forms the substance known in commerce as mace; in the yew (Fig. 328), it forms a drupaceous pseudo-berry.[1] Appendages of other kinds to the seed occur in the form of wings, as in Bignoniaceæ (Fig. 329), and Coniferæ (Fig. 304, p. 147), [in the latter case the wing does not belong to the testa, but to the woody scale to which the seed is attached], or hairs, as in Polemoniaceæ, &c. (Fig. 330).

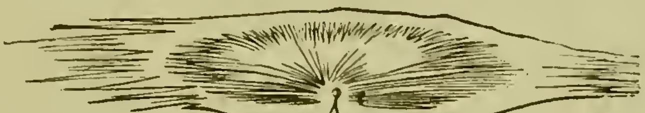
FIG. 329.—Winged seed of *Bignonia Catalpa.*

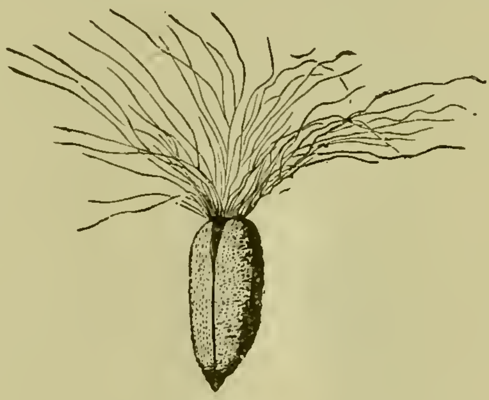
FIG. 330.—Ripe seed of *Epilobium*, with coronet of hairs (magnified).

The seed consists of an integument and a nucellus, the first being formed from the integuments, the last from the nucellus of the ovule.

The *integument* consists of an outer and an inner layer, the former being sometimes called the *testa*, and the latter the *tegmen.* In the walnut the outer layer is yellow and

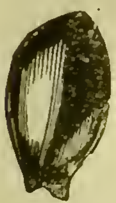
FIG. 331.—Smooth seed of *Aquilegia* (magnified).

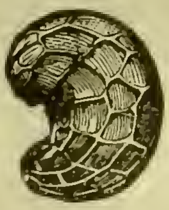
FIG. 332.—Reticulated seed of poppy (magnified).

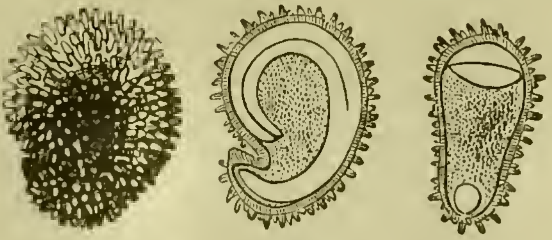
FIG. 333.—Spiny seed of *Stellaria*, entire and cut through, both lengthwise and transversely, showing the campylotropous form, the curved embryo surrounding a copious endosperm (magnified).

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[1] [The term aril is, strictly speaking, confined to a structure of this kind which springs from the hilum, as in *Passiflora*, *Taxus*, *Nymphæa*, &c. A similar structure, originating at or near the micropyle, as in *Euonymus*, *Euphorbia*, *Polygala*, &c., is a false aril or *arillode*; if from the testa, independent of the micropyle or funicle, as in *Chelidonium*, *Viola*, &c., a *strophiole* or *caruncle.*—ED.]

bitter; the inner layer thin and white. The testa is often leathery, crustaceous, or even stony [as in the Brazil-nut]; and is either smooth (Fig. 331), or with pit-like depressions (Fig. 332), or covered with spines (Fig. 333), and may be white or coloured.

The *nucellus* of the seed consists essentially of an *embryo*, in addition to which is found in the majority of seeds an *albumen* or *endosperm* (Fig. 333). Seeds are therefore distinguished into *albuminous* and *exalbuminous*. The embryo in its simplest form (Fig. 334), as in orchids, *Orobanche*, *Monotropa*, and *Cuscuta*, is a spherical body; but as a rule consists of an axis (Figs. 97–99, pp. 70, 71) and one or more leaves. The axis is differentiated at its apex into a *plumule*, distinct from the lower end or *radicle*. The leaves of the embryo are in most plants very characteristic, and different in form from the foliage-leaves which are subsequently developed, and bear the name of *seed-leaves* or *cotyledons*. They are sometimes thin and leaf-like, sometimes thick and fleshy. The green colour which many cotyledons assume as soon as they rise above the ground after germination is only developed under the influence of light; it is not found while they are still enclosed in the testa. The thicker and more fleshy cotyledons which often occupy the greater part of the seed, as in Leguminosæ, have scarcely anything in common with the later foliage-leaves of the plant, and generally remain underground after germination. Dependent on the number of cotyledons, plants are divided primarily into *Dicotyledones* with two, *Monocotyledones* with only one, and *Acotyledones* [flowerless plants], without any. A larger number of cotyledons than two is rare, and is peculiar to certain Coniferæ (Fig. 335). In a few cases, as the

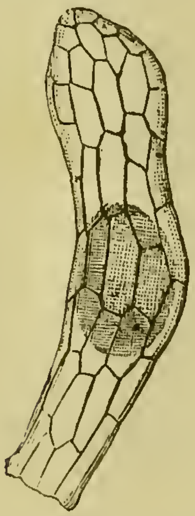
FIG. 334.—Globular embryo of *Pyrola*, with reticulated testa (magnified).

pea and bean (Fig. 98, p. 70), the embryo contains a few other leaves besides the cotyledons.

The relative position of the different parts of the embryo requires special notice. The most common arrangement is that found in Cruciferæ, where the embryo is *pleurorhizal*, the cotyledons lying flat one upon another, and the radicle upon the line which separates them (Fig. 336). In the *notorhizal* embryo (Fig. 337), the radicle lies upon the back of one of the cotyledons, which again lie flat one upon another. The embryo is *orthoplozic* (Fig. 338) when the radicle lies in the hollow channel of the folded cotyledons. In the *spiral* embryo (Fig. 339), the cotyledons are laid flat upon one another and coiled spirally. Occasionally the embryo is doubly spiral.

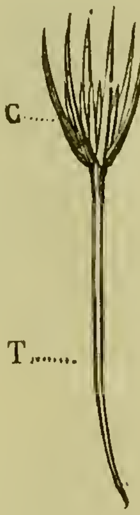

Fig. 335.—Embryo of Scotch fir, with six cotyledons, *c*.

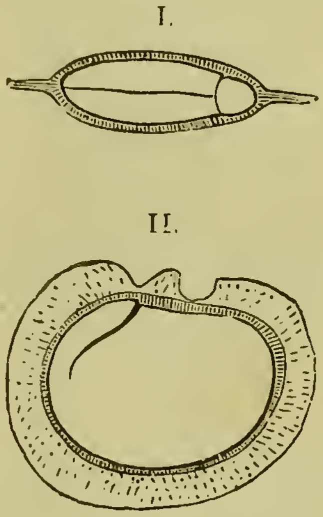

Fig. 336.—Pleurorhizal embryo of *Lunaria*; I. transverse; II. longitudinal section through the seed (magnified).

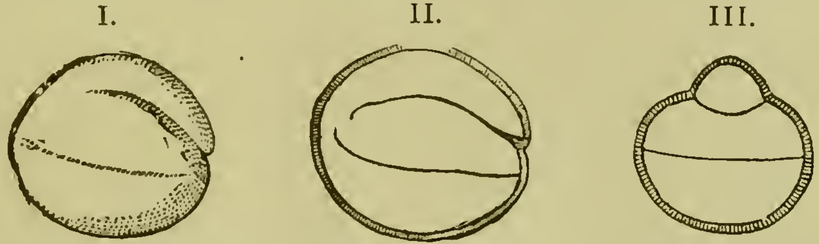

Fig. 337.—Seed of *Neslea paniculata*; I. entire; II., III., sections in two different directions showing the notorhizal embryo (magnified).

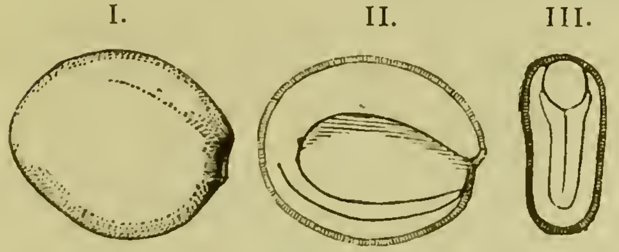

Fig. 338.—Seed of *Eruca sativa*; I., entire; II., III., sections in two different directions showing the orthoplozic embryo (magnified).

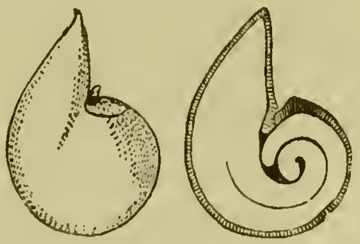

Fig. 339.—Spiral embryo of *Bunias Erucago* (magnified).

The position of the embryo in the endosperm also varies in different plants. It sometimes lies in the middle of the endosperm, when the latter is said to be *peripheric* (Fig. 340), as in *Iris*; sometimes outside it, when it is said to be *opposite* the lateral endosperm (Fig. 341); or *peripheric* and the endosperm central (Fig. 342). The texture of the endosperm also varies greatly; in the cereal grasses it is farinaceous or starchy, in the coffee-berry cartilaginous, in the vegetable ivory, *Phytelephas*, hard and white like ivory.

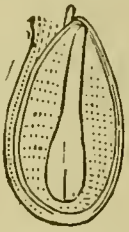

FIG. 340. — Peripheric endosperm surrounding the central embryo in the pansy (magnified).

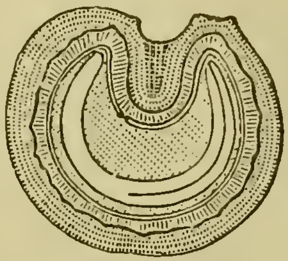

FIG. 341. — Lateral embryo of *Menispermum canadense* (magnified).

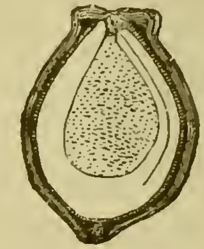

FIG. 342. — Peripheric embryo surrounding the central endosperm in *Mirabilis Jalapa* (magnified).

CHAPTER V.

THE LIFE OF THE PLANT.

THE life of a plant is in general apparently much more simple than that of an animal. Its vital phenomena are, however, in both cases, the result of the concurrence of two factors—its internal structure with the faculties belonging to this structure, and its external environment.

The theory is founded on a number of delicate experiments which cannot here be described, that all organised parts of plants consist of minute, solid, and crystalline particles called *molecules* or *micellæ*, which cannot, however, be distinguished by the most powerful lenses. This hypothesis does not assume that the molecules must always be spherical; they are often, on the contrary, supposed to have a crystalline structure. The adjacent molecules are not united by any solid connection, but are isolated one from another, and the reason of the solid condition of a body is that its molecules have a mutual attraction for one another; and the stronger this attraction, the more firm and solid is the body which they compose. Every molecule is in its natural state surrounded by a layer of water, so that they are completely separated from one another on all sides. Within certain limits a portion of their watery contents can be removed from organised structures, or they can take up fresh quantities, without being thereby destroyed or killed. Loss of water or desiccation causes a contraction, the absorption of water an increase or swelling of the body. The molecules of one and the same organised body separated by envelopes of water always differ chemically, so that molecules of a different chemical nature are found in the midst of and beside one another at every point that can be perceived by the microscope.

THE MOVEMENT OF WATER IN PLANTS.

It follows as a necessary consequence from the structure of organised bodies, that life is impossible in the most minute particles of the plant without access of water. The plant also requires water for the formation of organic substances out of the inorganic food-materials which it takes up, and furthermore, for the solution of solid substances stored up in it, the *reserve-materials*, which must be dissolved and transported to other places, where they are consumed. In addition to this the leaves lose in a short time a considerable portion of the water of their cell-sap by evaporation. In order to meet all these requirements, it is necessary that continuous *currents of water* should pass through the plant, and should be directed towards those parts where the plant requires it. The water, therefore, which is sucked up by the root-hairs flows through the roots like a system of rivulets, combining into larger streams or into a single current; and these then again ramify like the stem, and distribute themselves to the most delicate parts of the leaves, where the water again disappears in the form of vapour, by *transpiration*. It has been ascertained that in actively growing plants the quantity of water thus absorbed often amounts in a few days to many times the weight and volume of the whole plant. In true woody trees and shrubs, belonging to the Dicotyledons and Conifers, the less lignified portion of the alburnum serves especially as the conduit for this powerful stream ; in Monocotyledons, tree-ferns, and many herbaceous Dicotyledons, the woody parts of the vascular bundles. But the current is not confined to these parts, occurring also, though less actively, in the unlignified tissues, and in the substance of the cell-wall itself. The chief causes of these great movements of water are : *capillarity*, and diffusion or *osmose*. Acting in conjunction with this force is the *root-pressure*. The roots absorb a greater quantity of water than the plant requires ; and this, therefore, exercises a pressure which drives the water that has been already absorbed higher and higher up the stem ; and often, as in Grasses, Aroideæ, &c., even causes it to exude in drops at the margins and tips of the leaves. Experiments on the intensity of the root-pressure, performed

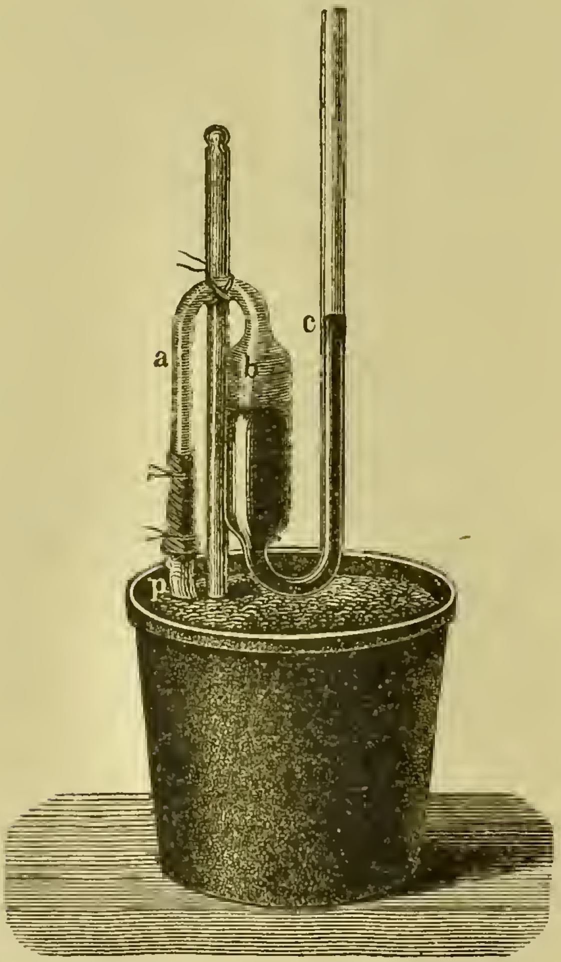

Fig. 343.—Apparatus for measuring the root-pressure. A manometer, *a*, *b*, *c*, is fixed into the upper part of the plant *p* growing in a pot, the top having been cut off. The difference in the height of the mercury in the two arms *b* and *c* indicates the intensity of the pressure by which the water sucked up by the roots is forced out at the cut section.

by cutting off the upper part of the stem, and attaching a manometer to the section, show that it is sufficiently powerful to balance a column of water more than ten metres in height (Fig. 343).

The organs of transpiration are the leaves, which allow of the escape through their stomata of the aqueous vapour that has accumulated in the intercellular spaces. The amount of transpiration depends on the moisture of the air, on the intensity of light, on the temperature, on concussions to which the plant is subject, and on the age and size of the leaves. It has not yet been ascertained how all these forces act; observation has nevertheless shown that the stomata are closed at night and open in the day-time under favourable circumstances, *i.e.* when the atmosphere is not too moist, and under the influence of light and warmth.

If the loss of water by transpiration from the leaves is greater than the quantity supplied by the roots, the conducting parts become first of all deficient in it; and when at length the evaporation from the more delicate organs can no longer be compensated, they lose their stiffness and hang down from their own weight, or in other words wither. This condition is caused at an earlier period in herbaceous plants than in succulent plants or trees which possess large reservoirs of water in their stems.

[The fluid which is contained in the alburnum of Dicotyledons is of a watery character, containing dextrine and sugar, but not starch, chlorophyll, or any colouring matter. It may also contain matters dissolved out in its course through the tissues, as well as mineral salts absorbed by the roots. This fluid is called *crude sap*, and occurs in special abundance in the spring. At this season it flows freely out from incisions made in the bark, as in the process known as the 'bleeding' of vines, &c. In the leaves this crude sap becomes converted into *elaborated sap*, which, in its descending current, produces the cambium and other formative tissues.]

ASSIMILATION AND METASTASIS.

The life of the plant is associated with a continual consumption of plastic substances, which are of service to it as formative materials for the growth of cells already in existence, and for the production of new ones. A number of the sources of force in the plant are being continually lost through these processes, because many of these formative substances then cease to exercise their chemical influence on one another. If the plant is not to perish from the deficiency thus occasioned of formative materials and of sources of force, or, as it were, to be starved, it must be supplied with nutrient substances, *i.e.* with chemical compounds which contain the substances that it requires. Only in comparatively few cases is a chemical compound absorbed into the plant which will be useful to it without change; as a rule, it is only the separate elements which are indispensable, and are on that account taken up out of their compounds. Those elements which are indispensable for the entire processes of vegetation are called the *nutrient substances* of the plant.

If we pass in review the elements which play this part in the vegetable kingdom, we find that the list comprises *carbon*, *oxygen*, *nitrogen*, *hydrogen*, and *sulphur*, because these enter into the composition of protoplasm, and are consequently necessary for the formation of every vegetable cell. To them must also be added *iron*, *calcium*, *potassium*, *magnesium*, and *phosphorus*, because no instance is at present known of a plant retaining its normal state of health if deprived of any one of these elements. *Sodium* and *chlorine* must also probably be included. In addition to these universally distributed nutrient materials, the growth of some plants is also dependent on the presence of other special elements; although we have no exact knowledge of the part which they play, and are unable to state positively that they are indispensable. Thus *Viola calaminaria* and some other plants always contain zinc, and will only grow on soil which contains that element.

The organ by means of which the nutrient substances are taken up is, in the lower plants, the entire surface; in the higher plants this function is specially assigned to the root, which is constructed for this purpose. In the case of roots which penetrate into the soil, only the youngest parts, with their delicate root-hairs and papillæ, can perform this function; but in the aërial roots of some plants, which are provided with a great number of hairs or with a root-sheath, the whole surface of the root appears to possess the power of absorbing nutrient substances in the form of vapour.

In addition to the roots, the higher plants possess also in the leaves organs which are adapted for the absorption of nutrient substances in a gaseous condition. But experimental observation has shown that the leaves, under ordinary circumstances, do not absorb fluid nutriment, either in the form of drops or of vapour, so as to carry it to the other parts of the plant.

Since the nutrient substances must pass through the closed walls of the cells in order to reach their interior, it follows that they must be present in a dissolved fluid or gaseous form. They are then received into the cells adapted for this purpose by means of *osmose*; since there are in general two fluids, the cell-sap and the water absorbed from the soil, capable of mixing with one another, and separated only by the permeable cell-wall. The absorption of nutriment is, therefore, only a mixing of two fluids of different densities.

The terms *osmose*, *diosmose*, and *diffusion* have been given to the mingling of fluids through a permeable partition-wall, *i.e.* one which has no visible perforations. If, for example, a vessel closed below by an animal membrane (Fig. 344 *b*) is filled with a concentrated solution of cupric sulphate (blue vitriol), and is then immersed in a vessel filled with water (*n*), the water will pass gradually through the bladder into the vessel *b*, and the fluid will rise in a tube *r* attached to it, while the level at *n* falls. If, on the contrary, the cupric sulphate were placed outside, and the water within the vessel *b*, the fluid would fall in the tube *r*, while the level *n* would rise. In both cases a small quantity of the cupric sulphate also passes through the bladder into the water, as may be seen by its colouration, but a very much larger quantity of water passes the other way. The process will continue until the two fluids on each side of the bladder have become homogeneous. The cause of the increase of the fluid on one side, and the decrease on the other side of the bladder, is that the water passes more easily through it than the solution of cupric sulphate does. But in other cases a very considerable interchange of the two fluids may take place without its being perceptible ; *viz.* when they are of the same colour and pass through the partition-wall in equal quantities. When two fluids are capable of diffusion—which is not always the case—a greater quantity of the less concentrated or lighter fluid usually passes through than of the more concentrated or denser. Cell-walls act in the plant exactly like an animal bladder in the instance adduced. In the process just described, the current which passes into an enclosed space such as a cell is termed an *endosmotic*, that which passes in an opposite direction an *exosmotic* current.

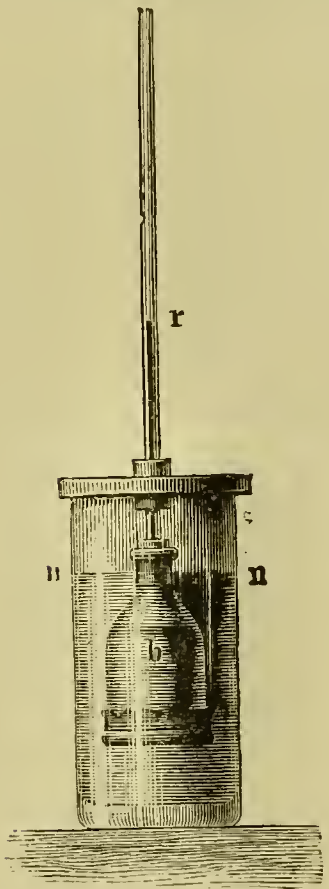

FIG. 344.—Apparatus for measuring osmose : *b* a vessel filled with cupric sulphate closed below by a permeable membrane, and placed in a vessel of water. As the water passes through the bladder to mingle with the cupric sulphate the level of the fluid will rise in the tube *r* in connection with the vessel *b*, but will fall at *n* in the outer vessel.

Since the cell-sap is much richer in substances which cause osmose [or is of a greater specific gravity] than the moisture of the soil, which contains in solution only a small quantity of salts, gases, &c., a considerable endosmotic current is set up of the absorbed moisture into the cell, while only a very small quantity of the cell-sap passes out into the ground. This last process has, however, nothing in common with the elimination of products of excretion which takes place in animals ; its purpose is rather to render soluble the insoluble constituents of the soil, and thus to enable the plant to absorb them in the water which it takes up. The membranes of the apices of root-hairs of plants which are still in active growth are so delicate that, in obedience to the force of gravitation, they come into intimate contact with all the unevennesses of the adjacent solid particles, and afterwards, by the hardening of the membrane, actually unite with them (Fig. 345). And since experiment has shown that the cell-sap is almost always acid, its passage into the ground causes the particles of soil with which the root-hairs have united to be gradually dissolved at the points of union, so that they can then be taken up into the plant.

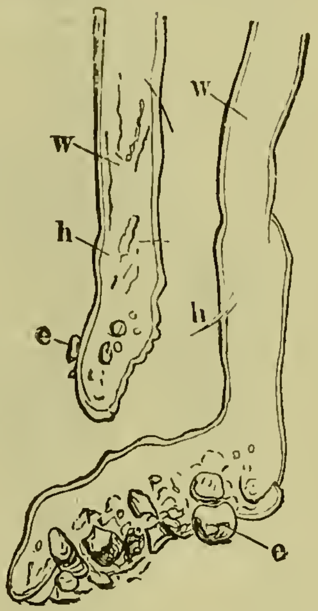

FIG. 345.—*w* Root-hairs of a seedling of wheat growing in loam, which have taken up minute stones and particles of soil *e* ; *h* smaller root-hairs. (× 800.)

[With regard to plants growing in the soil, the nutrient power of the roots is greatly increased by the singular property of the *circumnutation* of the rootlets, discovered by Darwin, by means of which their tips are constantly brought into contact with fresh particles of soil.]

The mode of nutrition of *parasites* is different from this. The roots of the more highly organised parasites, such as the mistletoe and the broom-rape, *Orobanche*, penetrate into another plant which is termed their *host* (Fig. 346), and take up from it nutrient substances which have already been to a certain extent assimilated. The lower parasites, such as certain Fungi, on the other hand, pierce by their cells the membranes of other cells, in order to live in and on them (Fig. 347). The mode of absorption of food-material and of the nutrition of *saprophytes* [or plants which live on decaying organic substances], such as *Monotropa Hypopitys* and certain Orchideæ, is still in doubt. The characteristic of these plants is that their absorptive organs take up certain products of the decomposition of organic substances, termed humus, and bring them again into requisition for nutrition, after undergoing some change.

Plants do not absorb the nutrient substances which are adapted to them unless presented to them in a suitable form; they do not for example, imbibe the free nitrogen of the atmosphere. Experiments, into the details of which we cannot enter, have given on this point the following results :—

The source of the *carbon* in those plants which contain

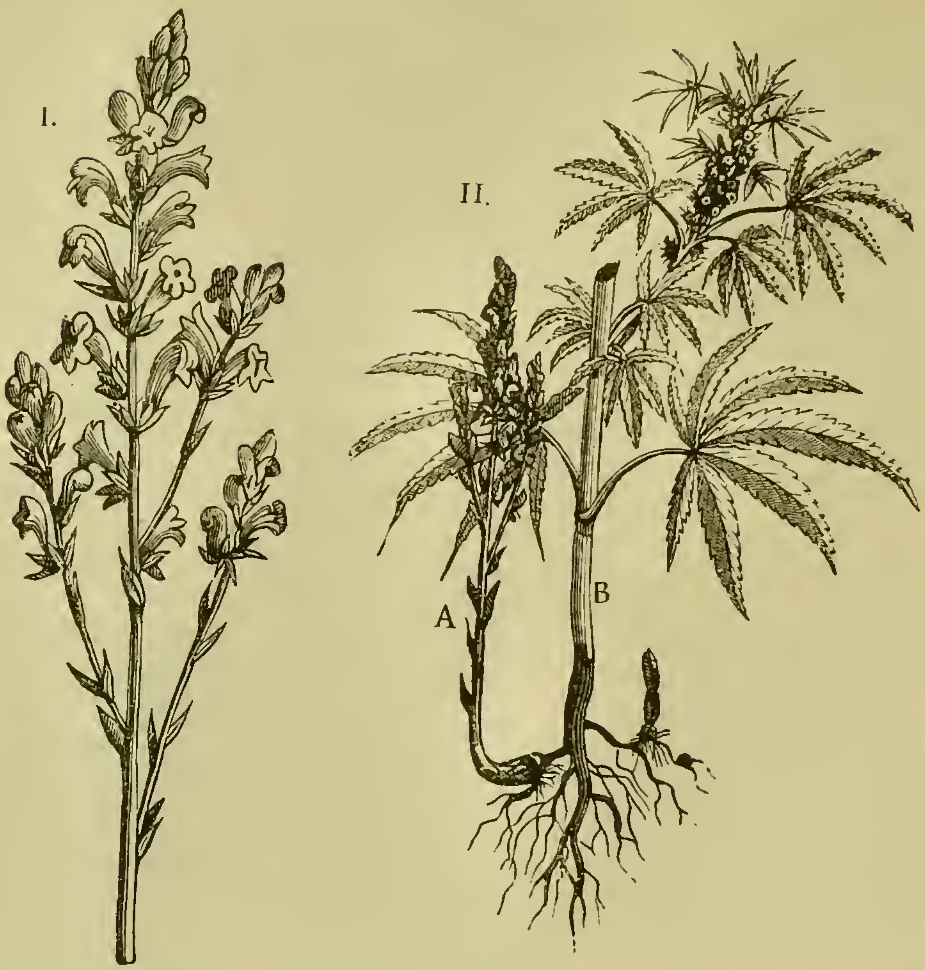

FIG. 346.—I. *Orobanche ramosa* (about one-third natural size); II. the same plant A parasitic upon the roots of a plant of hemp B (greatly reduced).

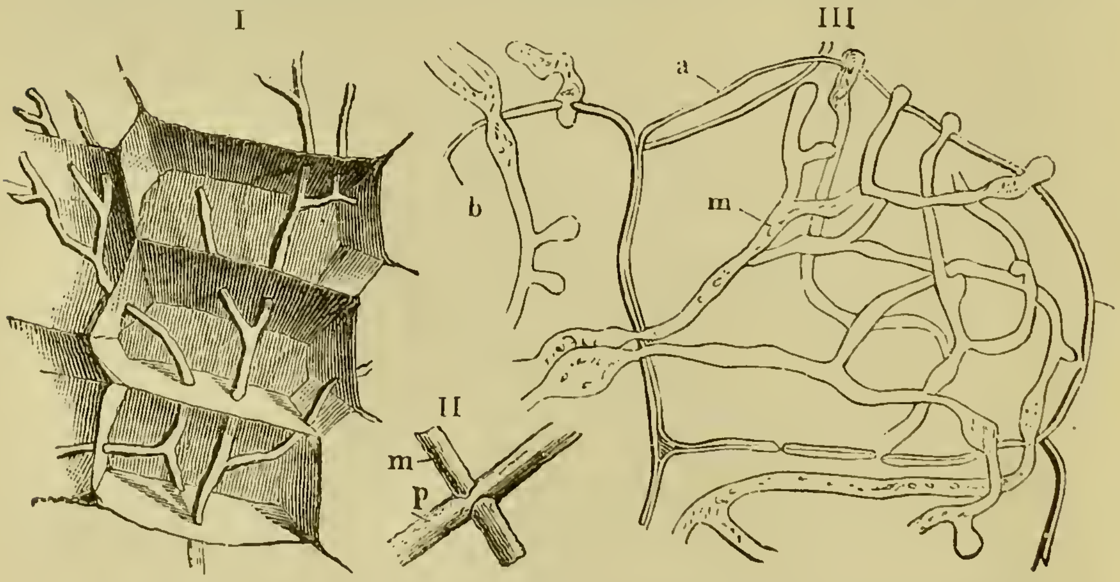

FIG. 347.—I. Diagram in perspective of the mode in which a Fungus-hypha penetrates through several cells; II. point at which a Fungus-hypha *p* has pierced through a cell-wall *m*; III. *a* parenchymatous cell from a rotten turnip; *b* part of an adjacent cell; both cells are penetrated by Fungus-hyphæ, *m*; a Fungus-hypha is in the act of piercing into cell *b*. (× 200.)

chlorophyll, and which are not parasitic, is mainly, if not exclusively, the absorption of carbon dioxide (carbonic acid gas) by those parts which contain chlorophyll, and its decomposition under the influence of light, the carbon being retained and the oxygen again given off. It is indisputable that in certain cases the humus can also contribute a supply of carbon for the nutrition of the plant; but the fact that in a soil which has not been affected by cultivation, as in a primeval forest, the stratum of humus does not diminish, but rather constantly increases, notwithstanding its continual decay and its consumption by plants and animals, shows that a much greater quantity of carbon must be derived from the atmosphere than from the soil.

Hydrogen, which, like carbon, is present in every organic compound, enters into non-nitrogenous combinations only through the decomposition of water; in those which contain nitrogen possibly also by the absorption of ammonia.

Oxygen is taken up into plants along with the elements already mentioned, the substances in which they occur being of such a nature that a large portion of their oxygen must be given off before they can be of any further use to the plant. The decomposition of the carbon dioxide of the atmosphere is a remarkable illustration of this. But, notwithstanding this excess of oxygen in the plant, the oxygen of the atmosphere is also absorbed; not, however, in order to form a part of any permanent compound, but, on the contrary, in order to decompose the substances contained in the plant, to deprive them of at least a part of their carbon, and to be again evolved as carbon dioxide. This process, the true *respiration* of plants, is very important; since it is always taking place in all living cells without exception; and the action of the inhaled oxygen is a necessary condition of the life of the protoplasm, and therefore of the plant. In relation to this, the experimental fact is of the greatest importance, that plants placed in pure carbon dioxide are suffocated, just as animals are. In some flowers and inflorescences, the production of carbon dioxide by the inhalation of oxygen is very energetic; and since the radiation of the heat produced by the oxidation is in these cases insignificant, from the surface being comparatively small or the parts protected by enveloping sheaths, very considerable elevations of temperature can be observed. At the time of the fertilisation of the spadices of Aroideæ, an elevation of temperature amounting to as much as 10° C. has been detected; and in the flowers of Cucurbitaceæ and of *Victoria regia* similar elevations have been observed, though to a smaller extent. Respiration is a process diametrically opposite to the process of assimilation which takes place in the cells that contain chlorophyll, and which consists in the absorption and subsequent decomposition of carbon dioxide, although this latter has also been described under the same name, a use of terms as incorrect as if we were to speak of an animal inhaling its food.

The free *nitrogen* of the atmosphere enters the plant through the stomata, and also by the process of osmose, but does not serve for nutrition; for the purpose of nutrition this element must be presented to the plant in the form of nitric acid or of an ammoniacal salt. Whether non-parasitic plants absorb nitrogen also in the form of certain organic compounds is still undetermined.

The only conceivable source of *sulphur* is the sulphuric acid of the sulphates present in the soil. It probably enters the plant only in the form of calcium sulphate, which is decomposed by the oxalic acid formed in the plant itself; this being the source, on the one hand, of the calcium oxalate, which so commonly occurs in plants [in the form of raphides], while on the other hand the sulphuric acid gives up its sulphur in the production of protoplasm and generally of albuminoids.

It is evident that the remaining nutrient substances can only enter the plant by the process of diffusion, and in general in the form of soluble salts; but their relations to the life of the plant are still obscure. With regard to *iron* we can form some judgment, since we know that its presence is necessary for the production of chlorophyll. Plants which grow in soil destitute of iron do not become green, but remain bleached or etiolated until enabled to do so by the addition of iron to the soil; though it is doubtful whether chlorophyll contains iron as one of its essential ingredients. Since etiolated plants, owing to the absence of chlorophyll, are unable to absorb carbon dioxide, they can live only for a short time, and soon perish. The salts of iron present in the soil afford the necessary supply of this element for vegetation. *Phosphoric acid* appears to stand in a certain relation to the production of albuminoids, or at least, is invariably found in association with them ; and in many seeds there is a constant relationship between the weight of the phosphoric acid and that of the nitrogen contained in them. With respect to *potassium*, similar general relationships to starch, sugar, and cellulose are not improbable ; and it is known that the amount of potassium in any part of a plant varies with the rapidity and energy of its growth. But in what form phosphoric acid and potassium enter the plant, and what their special functions are, is still unknown. *Silicic acid*, which constitutes the greater part of the ash in many plants, as, for instance, the stems of cereals, cannot be considered a nutrient substance in the same sense as those already described ; since it has been proved by experiment that it is not absolutely necessary to the growth of these plants, and its presence appears to be only a favourable condition to their perfect development. *Iodine* is taken out of the sea-water by marine plants.

[The remarkable phenomena connected with *Carnivorous Plants* have only recently been fully investigated. A few plants belonging to widely separated natural orders, the best known of which are *Drosera*, *Dionæa*, *Pinguicula*, *Nepenthes*, and *Sarracenia*, have the remarkable power of absorbing through their leaves substances containing nitrogen, by a process of true digestion, precisely analogous to the digestion of animals, due to the presence of a ferment identical with pepsin. The singular movements of some organs connected with this process will be referred to hereafter: they afford in some cases an extraordinarily delicate test for the presence of nitrogen. The phenomenon is accompanied by remarkable changes in the form and appearance of the protoplasm-body in the cells contiguous to those which are directly concerned in the absorption of the nutrient matter.]

If plants are grown in fluids which contain all the substances necessary for their life, it is found that these substances are not taken up in quantities dependent on the concentration of the fluid, nor on the proportion of the various substances contained in it; but that different species of plants, on the contrary, supply their needs from the same fluid in different ways. In consequence of this phenomenon, which depends on causes at present unknown, a quantitative 'selective power' has been ascribed to plants. With reference to the peculiarity that—setting aside nitrogenous food-materials—different species take up in preference different nutrient substances, plants may be distinguished as calcareous, alkaline, siliceous, &c. Leguminosæ, for example, are specially dependent on lime, potatoes and turnips on potash, all plants in which the seed is remarkably developed on phosphoric acid, cereals and grasses generally on silica, &c.

The cultivation of crops withdraws from the soil immense quantities of substances; so that sooner or later the moment must arrive when the produce will diminish, and at length altogether cease, unless those constituents of the soil which the crops have withdrawn from it be replaced. The object of the agriculturist must therefore be so to work his ground that the soil never becomes exhausted, but that he shall constantly obtain abundant crops and an adequate interest on his capital, the soil. There are two modes of securing this: by a carefully selected succession of different crops, and by manures. He must of course in addition depend on a suitable mechanical working, loosening, and irrigating of the ground.

In consequence of the selective power of plants, a succession of a number of crops of an alkaline plant causes the soil to become for a time—and at length when all the alkalies have been consumed, permanently - unproductive for plants of this description. But while the alkaline plant has the power of withdrawing an unusual proportion of alkalies from the soil, it leaves all the other nutrient substances comparatively untouched. These substances therefore accumulate in the soil, the small consumption of them being outweighed by the decomposing influence of the atmosphere, which is constantly reducing to a soluble condition small quantities of soil, and thus rendering their constituents available for nutrition. The substances which are thus made available for the plant are retained by fertile soils, and thus their solution by rain, &c. ensured for at least a sufficient time for the whole of the soil to become completely saturated by them. It is, therefore, essential to good agriculture that the crop of the alkaline plant should be followed by one of another kind, say a siliceous plant; and thus a well-chosen succession of different crops will remove from the soil one substance after another. This *rotation* must be continued until the substances first withdrawn are restored in such proportion and distribution that the same series of crops may again be grown. In former times the influence of the atmosphere on the soil was utilised by cultivating only a portion of the soil, the rest being left untilled or fallow; but it is now acknowledged that this mode of agriculture is not economical. In those districts where it pays to cultivate large tracts of land, no considerable portion is now left fallow; but the object is, by a good rotation of crops, to use up as equally as possible all the constituents of the soil. Even under the best system of agriculture, however, the soil must become gradually exhausted, and this exhaustion must be artificially counteracted. This purpose is effected by a scientific system of manuring, by which those substances are supplied to the soil of which it has most need. According to circumstances the most various organic and inorganic substances may be employed as manures. If, for example, there is a deficiency of nitrogenous substances, an addition of nitrates or guano is made. We cannot here enter further on the physical changes in the constitution of the soil, often so advantageous or even indispensable to vegetation, caused by the rotation of crops and by manuring. Care must on the other hand be taken not to impart to the soil such substances as are injurious to vegetation. Manuring with chlorides such as sodium chloride (common salt), for example, while increasing the weight of root-crops, has a decidedly injurious effect on their quality.

The nutrient substances taken up by plants are, however, by no means adapted, in the raw state, to take part in the construction of any vegetable structures; they must, on the contrary, undergo important transformations, and become changed into organic compounds suitable for nutrition. This process of *assimilation* may be compared to the digestion of food by animals, *i.e.* to its conversion into blood ; but still differs greatly from that process, since the animal takes up organic compounds already existing as such, which have only to undergo change, while plants have to construct more highly complicated out of simpler compounds, or, possibly, even out of their constituent elements. The fact that the compounds which are absorbed into the plant are usually very rich in oxygen, while the substance of the plant itself contains only a small proportion of that element, shows that assimilation must be a process of deoxidation or of elimination of oxygen. It can, therefore, take place only in those cells which contain chlorophyll, and under the influence of light ; because it is only in those parts of the plant, and only under the action of sufficient light, that oxygen is given off. The leaves are, therefore, the principal organs of assimilation.

It is not at present possible to follow step by step the process of assimilation ; it seems to depend mainly on the following forces : (1) the evaporation of the water contained in the nutrient sap by transpiration ; (2) the decomposition of carbon dioxide and the fixation of carbon ; (3) the formation of albuminoids which are essential for the production of protoplasm and chlorophyll ; (4) the formation of the substances from which cellulose is produced, *viz.* starch, the different kinds of sugar, oil, and inulin.

Since the growth of plants can take place only at the expense of assimilated substances, it is of the highest importance that a number of the products of assimilation should be transported from the places where they are produced, and made to take their part in the vital processes of the plant ; and they have therefore to be stored up at certain points, in order to serve, as required, as *reserve-materials.* Some of these reserve-materials are, for example, again dissolved in the spring at the commencement of the period of vegetation, and then employed in the production of new organs, especially the leaves.

The decomposition of the carbon dioxide contained in the atmosphere is the main source of the carbon required for building up the tissues of plants. Only those cells which contain chlorophyll, and then only under the influence of sunlight, have the power of decomposing the carbon dioxide which they take up, and of producing organic compounds out of its elements and those of water, with elimination of an equal volume of oxygen, or in other words of assimilating. It is highly probable that in this process the carbon dioxide loses only one half of its oxygen, the other half of the oxygen which is evolved resulting from the decomposition of water. It is only living chlorophyll that has the power of decomposing the carbon dioxide ; and in general both sides of the leaf take part in this process, though with different energy. Light and heat are absolutely necessary for it ; a small deficiency of heat may be compensated by more intense light, but there are limits which cannot be passed (see Fig. 373, p. 213). Plants which do not contain chlorophyll have no power of decomposing carbon dioxide, and hence of assimilating ; they must therefore obtain their nutriment from substances already assimilated ; and hence grow either on or in animals or other plants as parasites, and obtain their nutriment from them, or live [as saprophytes] on organic substances actually undergoing decomposition, and absorb their organic constituents before they are completely decomposed.

The mode of formation of *albuminoids* is still unknown ; it has not even been accurately ascertained at what spot they are produced. The most probable solution is that they are formed at those spots where calcium oxalate is stored up, because this salt is formed by the decomposition of calcium sulphate, the sulphur of which passes over into the albuminoids (See p. 168).

Neither is it yet known how *cellulose* is formed, although access of atmospheric oxygen appears essential to its production. It is tolerably certain that starch, sugar, inulin, and oil are the materials out of which the protoplasm constructs the cell-wall ; at least substances of this description which are stored up in the cells always disappear when an energetic formation of cellulose is going on.

Starch is invariably formed originally within the grains of chlorophyll. Light is necessary for this ; but the very small intensity of light which suffices for the formation of chlorophyll is not sufficient for that of starch or of the drops of oil which sometimes replace it. In direct sunshine starch is produced in the green parts of plants almost at the very moment in which the rays of light fall upon them; and in diffused daylight after a short time. Plants grown in the dark, and therefore etiolated, develope chlorophyll first when exposed to light, and then starch in the chlorophyll-grains. In the dark, starch is transformed into other nearly related but soluble substances, such as sugar, dextrin, &c., which become distributed through the whole plant, and is again fixed in the form of starch as a reserve-material at particular places, as in the grains of cereals, the tubers of the potato, &c. Whether or to what extent the nitrogenous constituents assist in these processes is still unknown.

The processes of life cannot be conceived as going on, even in unicellular plants, without a continual movement of those substances which are necessary to their life. In the most simply organised plants these processes are simple, but become more complicated as we ascend in the scale.

The direction in which the assimilated substances move varies according to the vital needs of the plant. They can be transported from the places where they are formed directly to those where they are required, or to *reservoirs of reserve-material*, where they are stored up until they are again carried to the parts where they are consumed. Hence perennial plants have their chief reservoirs in their stems, rhizomes, bulbs, or tubers; while those which do not bear fruit more than once have the greater part of their assimilated substances stored up in their seeds.

It may be taken as nearly certain that in plants higher in the scale than Mosses, in most if not in all cases, the transport of the assimilated nutrient sap takes place through two forms of tissue. The soft-bast is chiefly, though not exclusively, the conducting tissue of the albuminous mucilaginous alkaline compounds; while the parenchyma, both of the cortex and of the pith, is the chief agent in the conduction of non-nitrogenous substances, such as starch, sugar, inulin, oils, and acids. The laticiferous and the utricular vessels also contain reserve-materials of a different kind, which can be made use of when required; but the movement of the fluids contained in them is more sluggish than in a small-celled tissue.

The experiments of Hanstein were the first to prove this point. From the cut branches of various dicotyledonous plants he removed, above the cut surface, a circular piece of bark, and then placed the branch in water. The result was that in those species which possess no isolated vascular bundles, no cambium cells, and no sieve-tubes in the medullary sheath, no roots sprang from below the place from which the bark had been removed, or at least very few in proportion to the size of the piece of bark below; while above that part a large number of strong roots were formed (Fig. 348). In those plants, on the other hand, like *Mirabilis Jalapa* and *Amaranthus sanguineus*, which have isolated vascular bundles in the pith, or, like *Nerium Oleander* and *Solanum Dulcamara*, cambium-bundles or sieve-tubes, an abundance of roots were formed even below the part where the bark had been removed. The conclusion is unavoidable that substances essential to nutrition are conducted only through the elongated cambium- or sieve-tube cells. In these cell-bundles, however, non-nitrogenous substances occur only exceptionally, that is only at periods when large quantities must be transported in a short time; and in many plants they are never found there. The conclusion may hence be drawn that other groups of cells besides the elongated ones also take part in the transport of the assimilated sap; and these are most probably certain groups of parenchymatous cells which are distinguished by containing very fine-grained starch, and which can be recognised at once by this.

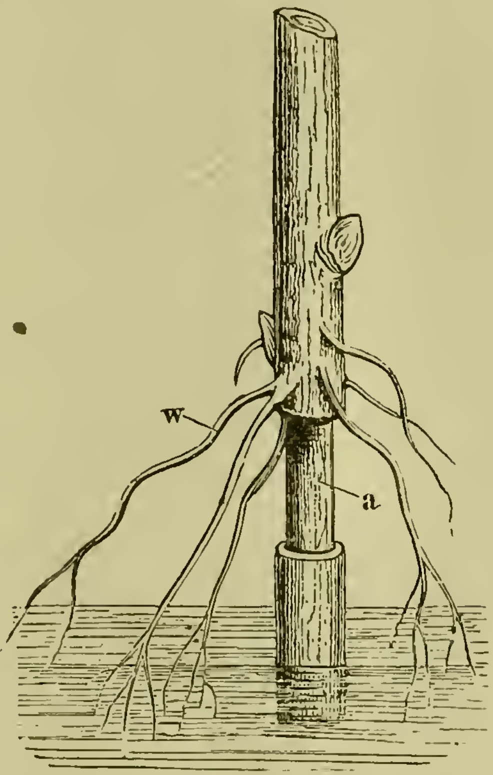

FIG. 348.—A cutting from which a ring of bark has been removed placed in water; from above this place *a* adventitious roots *w* are developed.

It follows from what has been said that the old view of an ascending sap in the spring and a descending current in the autumn, must be modified; that the sap certainly rises in the spring after the close of the winter's period of rest; but that this ascending current continues through the whole period of growth, as does also the descending current; and that, as need arises in the plant, horizontal currents also pass through its tissues. The old comparison between the circulation of the blood in animals and that of the sap in plants must therefore be entirely abandoned.

If now we inquire what are the causes of the movements of the assimilated nutrient sap, it is impossible to give a definite answer, because the action of organised and living protoplasm introduces indeterminable factors. It may, however, be assumed that the law of diffusion in its widest sense is one cause of these currents. The movement in cells enclosed on all sides is brought about by two causes: the *force of osmose* and the *tension of the tissues*, that is the force exercised on the conducting cells by the surrounding ones. The movement of the sap can take place more readily in intercommunicating tubes than in closed cells, as is seen in laticiferous vessels and sieve-tubes. Thus, for example, in the celandine, *Chelidonium majus*, the slight rise in temperature caused by the approach of the hand at the distance of an inch is sufficient to cause a current of latex towards the colder parts which may be perceived under the microscope. This movement is obviously occasioned by the pressure or tension which the swelling of the neighbouring cells exercises on the thin-walled laticiferous vessels. Other forces besides those already mentioned operate in these tubes, especially the curvatures and torsions of particular parts of the plant occasioned by the influence of light, gravitation, and the wind.

The products of assimilation, when transferred to other cells, and when brought into actual use, undergo a variety of changes which are included under the term *metastasis* or *metabolism*. Thus when the starch formed in the leaves of the potato is to be transferred into the tubers as a reserve-material, it must first be transformed into a soluble substance, viz. *glucose*. This glucose is distributed through the conducting tissues; and being again transformed into starch in the cells of the tuber, all the starch gradually collects in these organs. By the close of the period of growth, all the chlorophyll-grains are also dissolved and carried into the permanent organs, together with all the other substances which are subsequently to be employed. Many products of metastasis are of no further use in the construction of new cells, but remain stored up and inactive at the spots where they are produced. These are termed *secondary products of metastasis*, and comprise the volatile oils, resin, caoutchouc, gum-like substances, tannin, pigments, acids, alkaloids, wax, pectin, &c. Other substances, known as *degradation-products*, are produced only by subsequent changes in the substance of organised structures; such are the mucilage of quince-seeds and linseed, and perhaps also lignin and cork (see p. 23).

The object of the processes of assimilation and metastasis, the nutrition of cells already existing and the formation of new ones, is at present known only in its most general features. The little that is known consists of the laws of cell-formation already mentioned, and of the fact that the cell-wall grows by *intussusception*, that is, by the formation of fresh molecules between those already in existence.

REPRODUCTION.

The great office assigned to vegetation of covering the surface of the earth with forms of organic life, and transforming inorganic into organic substances in order to support the life of man and other animals, requires that plants be endowed in a remarkable manner with the power of reproduction, that is, of producing individuals of the same species, in order that the short duration of all earthly life may not result in the world being soon deprived of its covering of vegetation, and all life perishing in consequence. For this purpose, particular cells of the plant begin, at definite times, an independent growth, and thus carry on a life of their own, often not in connection with the parent plant. Such cells are called *reproductive cells*, and the plant which results from one of them constitutes a distinct *generation*. The successive generations are only rarely, as in some Algæ and Fungi, alike; as a rule, generations of a different kind follow one another. For example, a generation of the kind A will produce one of the kind B, and this again one of the kind A. This kind of development is called an *alternation of generations*.

Processes of reproduction are, again, of two essentially different kinds. While one class or group of reproductive cells are capable, without further preparation, of giving rise to a new plant, another class only have this power imparted to them by other cells which stand to them in a relation of contrast. The former kind are termed in general *non-sexual reproductive cells*, the latter *germ-cells* or *oospheres.*

Reproduction by non-sexual reproductive cells [*non-sexual reproduction*] occurs in a variety of modifications, some less, some more perfect, and is variously termed reproduction by *spores*, *gemmæ*, *bulbils*, *conidia*, *buds*, *gonidia*, &c.

The most common mode of multiplication in the lower plants is by means of *spores.* This term may, in general, be applied to all those simple reproductive cells which arise without any process of sexual union. In by far the greater number of cases they are simple cells enclosed in a single or double cell-wall, and formed at particular places, very commonly in special receptacles to which the name *sporangia* is given. The great variety that prevails in the form, function, permanence, and mode of formation of spores has led to the use of a number of special terms, of which those in most common use will be hereafter mentioned and explained. (See *e.g.* Figs. 394, 395, 400, 402.)

Conidia are scarcely distinguishable from spores; the term is applied especially to the non-sexual reproductive cells of certain groups of Fungi; they are always naked, never enclosed in a sporangium.

Gonidia are reproductive organs consisting of chlorophyllaceous cells; they are peculiar to Lichens, and are regarded as a peculiar form of lowly developed Algæ. (See Figs. 412, 413, pp. 287, 288.)

In *gemmæ* the cells are united into regular groups, and only in this condition detach themselves from the parent plant. They occur especially in the Muscineæ. In the Hepaticæ they are developed in special bowl-shaped conceptacles (Fig. 349); in Mosses, on the contrary, on the stem, rhizoids, leaves, and in short on all parts of the plant.

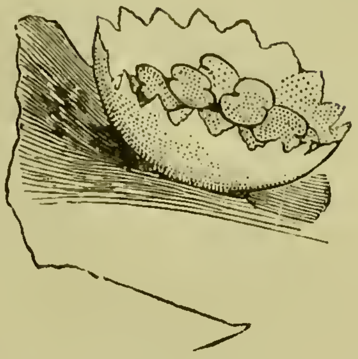

Fig. 349.—Conceptacle containing gemmæ of a Liverwort, *Marchantia polymorpha* (magnified).

Special interest attaches to the mode of reproduction by means of *buds*. These are larger assemblages of dissimilar cells, and are moderately highly organised germs of new plants, inasmuch as they already consist of axial and foliar organs. They are also not distributed irregularly over the parent plant, like the reproductive organs already mentioned, but are usually attached to definite positions, being found most commonly in the axils of leaves. The mode of reproduction by buds is of the highest practical importance, and is made use of by gardeners in a great variety of ways, since by this means not only is the species but the particular variety propagated, which is not always the case in reproduction by seeds. To this class belong reproduction by *bulbils*, *runners*, *cuttings*, *grafting*, *layering*, and *budding*. In these processes, so different in their external appearance, reproduction depends simply on the further development of buds which have become spontaneously detached from the parent plant, or artificially separated from it.

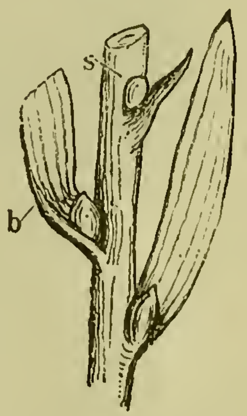

Fig. 350.—Stem of *Lilium bulbiferum*; *s* bulbils developed in the axils of the leaves *b*.

Bulbils are endowed in a high degree with the power of independent life; they become spontaneously detached from the parent plant, and, when they fall to the ground, continue to grow like seedlings. They occur especially in bulbous plants; in the hyacinth, for example, in the axils of the bulb-scales (Fig. 122, p. 82), in some lilies in the axils of the foliage-leaves (Fig. 350), and in some species of *Allium* within the inflorescence. More rarely they are found on the surface of the leaf, as in *Cardamine pratensis*, [*Bryophyllum*], and some Ferns.

Multiplication by the division of underground [or aërial] stems, as in the *Aster* and couch-grass, *Triticum repens*, and by *runners*, as in the strawberry, is so simple and so well known as not to require further description.

While in all the cases already described buds which have separated spontaneously from the plant have at once a power of new growth; in cuttings, grafts, layers, and buddings, on the other hand, the wound caused by an artificial and violent separation must first heal. The formative cambium is excited into activity, masses of succulent cells are formed, swell up to a certain extent between the innermost layer of bark and the wood, and spread laterally over the cut ends of both xylem and phloëm, these latter taking no part in the formation of new tissue (Fig. 352). Thus is formed a spongy, cartilaginous, succulent cushion of tissue, known to gardeners as a *callus*. At the same time the outer wounded parts of the bark, and sometimes also the pith, are

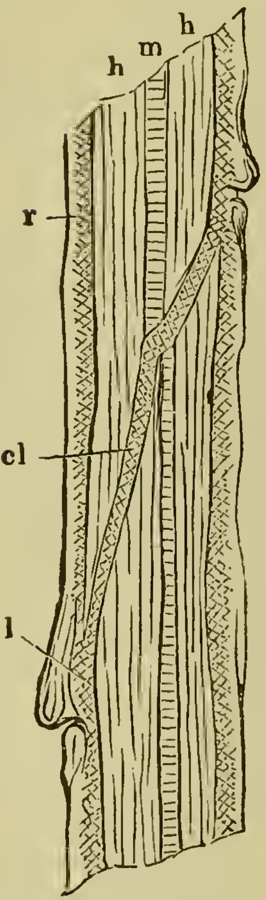

FIG. 351. — Diagrammatic representation of a longitudinal section through a graft; *cl* the callus; *r* bark; *m* pith.

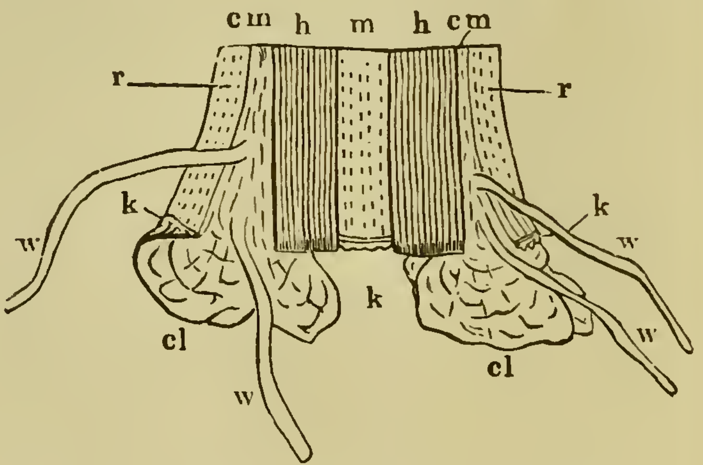

Fig. 352.—Diagrammatic representation of a longitudinal section through the lower end of a cutting; *cl* the callus; *cm* cambium; *h* wood; *k* cork · *m* pith; *r* bark; *w* roots.

protected from further injury by a newly formed cork-tissue. In *cuttings* (Fig. 352), *i.e.* cut branches planted in the earth, the roots are developed either through the tissue of the callus or near it, but always directly from the cambium. In grafting, layering, and budding, the cambium plays the same part as in the cutting, giving rise to the recuperative mass of healing tissue, or callus. This forces itself into the injured space between the bark and the wood (Fig. 351), fills it up in all directions, covers up the dead parts of the tissue, and causes those parts that are still active to coalesce with one another. The various modifications of this process are of greater interest from a practical than a scientific point of view. In *grafting* (Figs. 351, 353), a branch of a superior variety is planted on a stock of a wild variety. In *budding*, a bud to which a piece of the bark is still attached is inserted into a T-shaped incision beneath the bark of the stock (Fig. 354). In all cases the wounded part must be protected externally by wrapping round with bast and covering up with cotton-wool or some other substance from the injurious influence of the atmosphere. In these various processes the point of junction between the stock and the graft forms a boundary-line ; all the parts

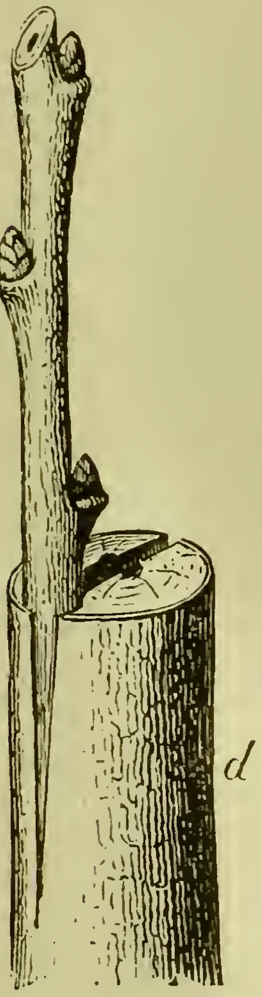

FIG. 353.—Grafting ; *d* the stock to which the graft is attached.

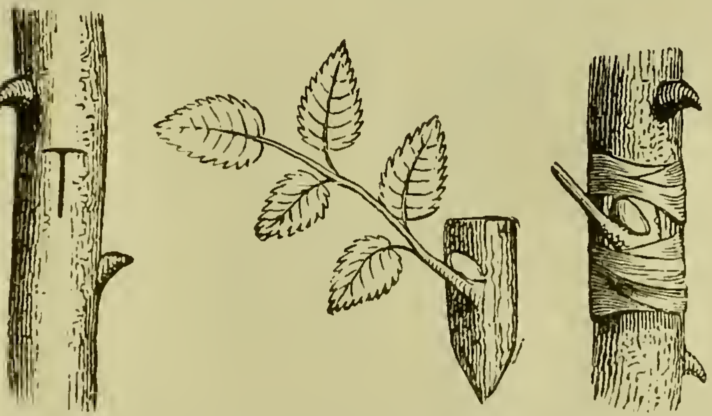

FIG. 354.—The various elements in the process of budding.

developed above this line belong to the latter ; all those beneath it to the stock. The graft is developed altogether spontaneously, without undergoing any essential change from the stock [1] ; while the stock, if the buds formed on it are allowed to grow, developes its own proper leaves, flowers, and fruit.

This independent growth of a bud in contact with the stock of another plant takes place, however, only when the two belong to nearly related species. The peach can be grafted on a plum-stock, but not the rose on an oak.

Reproduction by means of *oospheres* or *germ-cells* is essentially different from the modes already described ; since here cells of two different kinds are necessary to produce the new plant by their mutual action the one on the other, the cells of each kind having no power of propagation in themselves alone. This process of mutual action is called *fertilisation* or *impregnation*, and involves a distinction between the fertilising or *male*, and the fertilised or *female* element ; it is hence also known as *sexual reproduction.* The female element becomes, after fertilisation, the germ of the future plant.

Of the various processes of fertilisation we can here only describe that which is characteristic of all flowering plants or Phanerogams. The organs of reproduction—the male *pollen*, and the female *ovule*—are in them collected in the *flower*, and form its essential constituents, and fertilisation consists in the pollen exercising an influence on the ovule, by which a further development is induced in the latter. In those plants in which the ovules are enclosed in an ovary (Angiosperms) it is necessary that the pollen should, in the first place, fall upon the stigma. The period of maturity of the pollen and of the capacity of the ovule for fertilisation generally coincides with that of the expansion of the flower.

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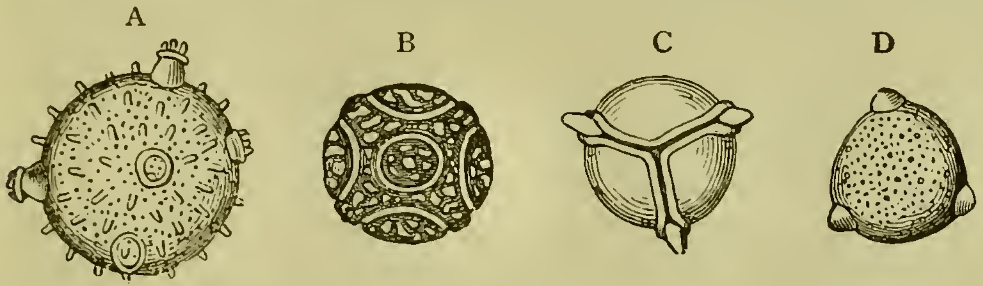
[1] [The graft and the stock do, however, exercise a certain amount of reciprocal influence the one on the other ; and in certain cases hybrids or intermediate forms between the two are produced.—Ed.]

The anthers then open, and the pollen-grains (Fig. 355) are carried to the stigma, either by the wind [*anemophilous*], or by the agency of insects [*entomophilous*], or by peculiar movements (see pp. 203, 205) of the stamens or carpels, and remain attached to it in consequence of its exuding a viscid fluid. If we consider the immense number of pollen-grains produced in any individual flower, and in addition the fact that a single one of these grains suffices for the fertilisation of an ovule, it would appear at first sight as if ample provision were made in the majority of plants for this first act in the process of fertilisation, especially if attention is directed to the relative positions of the anthers and stigma. Thus, for example, in most plants with pendent flowers, such as the fuchsia, the anthers are always placed higher than the long-styled stigma, so that in the act of *pollination*, that is, the dispersal of the pollen, some pollen-grains must almost inevitably become attached to the stigma. But in spite of the frequent occurrence of such favourable arrangements, there are many cases in which fertilisation is impossible without foreign aid, as in the Orchideæ and Asclepiadeæ (Fig. 355 E), in which the pollen-grains are firmly united together by a viscid substance into a pollinium, and lie undisturbed in the open anthers. In these cases assistance is given by the host of insects which, in their search for honey, fly busily from flower to flower,



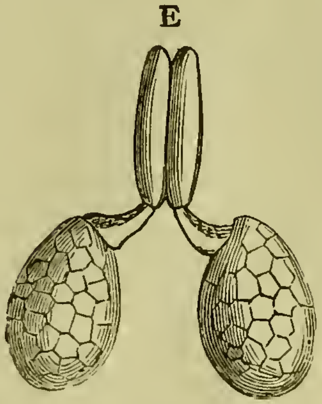


FIG. 355. — Pollen-grains; A *Cucurbita*; B *Passiflora*; C *Cuphea platycentra*; D *Dipsacus Fullonum*; E pollen-masses (pollinia) of *Cynanchum vincetoxicum* (Asclepiadeæ).

penetrate to the nectaries, and unintentionally and unknowingly carry the fertilising pollen from one flower to another. In a large number of flowers, as, for instance, the Leguminosæ, other contrivances are also found, by means of which the pollen is conveyed to particular parts of the bodies of the insects in their search for honey, *viz.* to those which must come into contact with the stigma when the insect visits the next flower. And since many insects, and especially bees—the most efficacious class in the fertilisation of flowers—habitually visit in succession a great number of flowers of the same kind, the pollen is not, as a rule, wasted by being carried to a flower of a different species. Too great importance cannot be attached to this function of insects; and many exotic plants, such as the vanilla, were long cultivated in our hot-houses without producing fruit, because the insects required for their fertilisation were wanting, until their place was supplied by artificial pollination.

In particular cases, in which fertilisation would otherwise be impossible, other special contrivances are found, especially in water-plants. When the pollen-grains come into contact with water, with a very few exceptions (as in *Ceratophyllum* and *Zostera*), they absorb so much as to cause them to burst, or to occasion the escape of their contents from one of their pores so quickly that they perish. In order to prevent this injurious effect it is almost invariably the case that submerged plants raise their flowers above the water, as in *Sagittaria* and *Hydrocharis*. In *Utricularia* (Fig. 356) the bladders on the leaves, which are previously empty, become filled with air at the time of fertilisation, raising the whole plant to the surface of the water, while it again sinks at the close of the period of flowering. The most remarkable case is, however, presented by *Vallisneria spiralis*. The male flowers are seated on very short pedicels at the base of the leaves, often several feet below the surface of the water; the female flowers on the contrary on very long pedicels, which at a particular time become greatly elongated and raise the flowers to the surface of the water. The male flowers then become detached from their pedicels, rise to the surface, are floated among the female flowers, and fertilise them. After this has been accom-

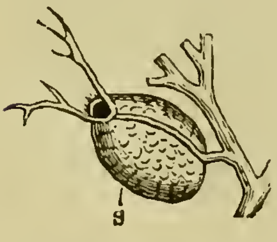


FIG. 356. *s* Bladder from a leaf of *Utricularia vulgaris.* (× 4).

plished the pedicel of the female flower coils up spirally, and the fruit ripens beneath the water.

Notwithstanding that appearances would seem to point to the pistil being always pollinated by the stamens which surround it, more exact observation has nevertheless shown that *self-fertilisation* of this nature does not, as a rule, take place, but that on the other hand *cross-fertilisation*, *i.e.* a crossing between different flowers on the same plant, or between flowers on different plants of the same species, is much more frequently actually found in nature. Illustrations of this law are found in the phenomena of dichogamy and heterostylism, which are found to occur in so many plants.

By *dichogamy* is meant the maturing at different times of the reproductive organs in a hermaphrodite flower. Dichogamous flowers are either *proterandrous*, when the pollen escapes from the anthers before the stigma in the same flower is ready for pollination, or *proterogynous*, when the stigma has lost its capacity for pollination before the pollen is mature, so that its pollination must depend on the pollen of older flowers. Most species of *Geranium*, *Pelargonium*, *Malva*, Umbelliferæ, Compositæ, and Campanulaceæ, are proterandrous; while among proterogynous plants [which are much less common] may be mentioned species of *Magnolia*, *Aristolochia*, [*Scrophularia*, *Plantago*], &c.

Heterostylism consists in different flowers belonging to the same species having stamens and pistils (styles) of different lengths. Thus, for example, in the cowslip [and primrose], *Linum perenne*, and *Pulmonaria officinalis* (Fig. 357), two different forms occur, the long-styled (I.), and the short-styled (II.). This difference in the form of the reproductive organs is called *dimorphism*; while *trimorphism*, or the existence of three different forms, occurs in *Lythrum Salicaria* [and *Oxalis*]. In plants in which this arrangement occurs, fertilisation,

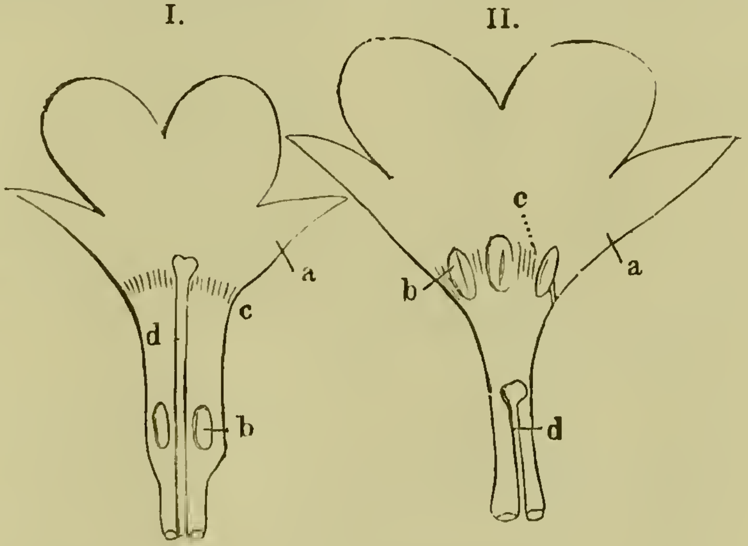


FIG. 357.—Dimorphic flower of *Pulmonaria*: I. long-styled; II. short-styled form. *a* corolla; *b* anthers; *c* ring of hairs; *d* pistil.

or the production of fertile seeds is, as a rule, effected only by the union of the reproductive organs which stand at the same height, and which are therefore always found in different flowers (Fig. 357 I. *b* and II. *d*, and I. *d* and II. *b*); [it is obvious that this will easily be brought about by the agency of insects. In many cases the stigma is absolutely sterile to pollen from the same flower; while in others pollen from a different flower is *prepotent* over that from the same flower.] Finally, the circumstance is specially noteworthy that in some Orchideæ the pollination of the stigma by pollen-grains from the same flower is actually poisonous, having a fatally injurious effect on the whole flower.

[Not a few examples are known of plants producing two kinds of flowers, one kind with conspicuous corolla, which may or may not be fertile; the other kind, known as *cleistogamic*, closed, with the corolla wanting or very imperfect, always fertile and self-fertilised. Very good examples occur in the sweet violet and common dog-violet.]

When pollination has been fully accomplished, the pollen-grain, excited by the viscid fluid exuded by the stigma, puts out one or more long tubes, the *pollen-tubes* (Fig. 358). [The pollen-grain of Angiosperms is now known—at least in a large number of cases—not to be unicellular, as previously supposed, but to resemble that of Gymnosperms in consisting of one large and several very much smaller cells. The large cell contains a fluid known as the *fovilla*, and very commonly two nuclei, and from it alone the pollen-tube is formed. The pollen-grain is invested by two coats, an inner coat, the *intine*, composed of cellulose, and an outer cuticularised coat, the *extine*, which is very commonly furrowed, warty, or spiny. The extine is either thin or entirely wanting at certain spots, beneath which the intine is exceptionally thick. The pollen-tube is formed from these accumulations of cellulose in the intine bursting through the weaks spots in the extine.] It penetrates through the conducting tissue

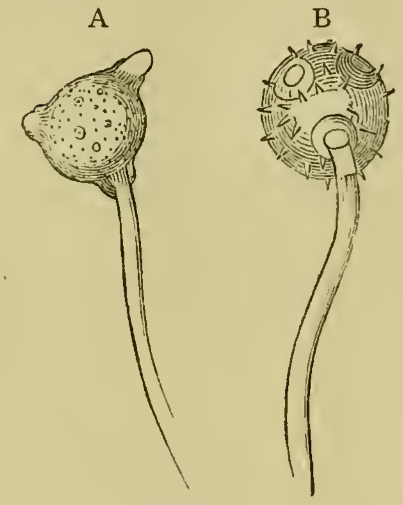


Fig. 358.—Pollen-grains putting out their pollen-tubes; A *Dipsacus Fullonum*; B *Cucurbita*.

of the style, and reaches the interior of the cavity of the ovary, often in a few hours. There it comes into contact with an ovule and attaches itself closely to it (Fig. 359). One of the cells of the nucellus of the ovule has, in the meantime, grown much larger than the rest, and has pressed aside and absorbed the surrounding tissue. This is the *embryo-sac*, [the mother-cell of the oosphere, containing one large nucleus, which is originally towards its lower end, *i.e.* away from the micropyle. As the embryo-sac increases in size before fertilisation, this nucleus divides, and the two daughter-nuclei travel to opposite ends of the sac, a large central vacuole being formed. Each of these nuclei again divides, and there are now four at each end of the sac, constituting the *polar* nuclei. Subsequently two of these, one from each end, approach and coalesce, constituting the permanent nucleus of the embryo-sac. The nuclei at the basal end of the sac soon become invested with cell-walls, and are called the *antipodal cells* (Fig. 360, *g*) ; their function is unknown, and they soon disappear. Those at the upper end of the sac are the *germinal* or *embryonic vesicles*, or the *egg-apparatus* (Fig. 360, *k*). Two of these, lying nearest to the apex of the sac, have been

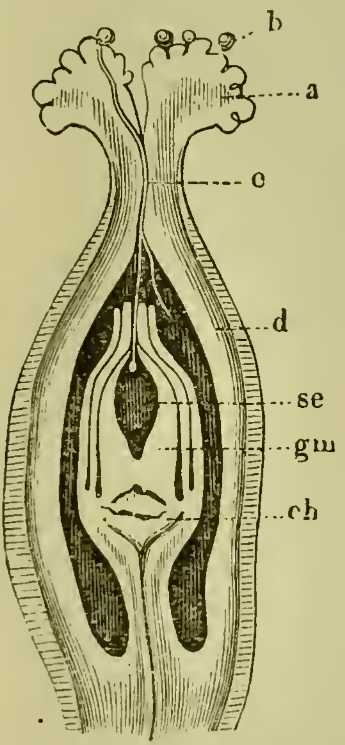


FIG. 359.—Longitudinal section through the uni-ovular ovary of *Polygonum Convolvulus* at the time of flowering : *a* stigma ; *b* pollen-grains ; *c* pollen-tube ; *d* wall of the ovary ; *gm* the erect orthotropous ovule ; *se* its embryo-sac ; *ch* chalaza ; two pollen-tubes have penetrated through the conducting tissue of the style, one of which has entered the micropyle of the ovule, the other not. (× 40.)

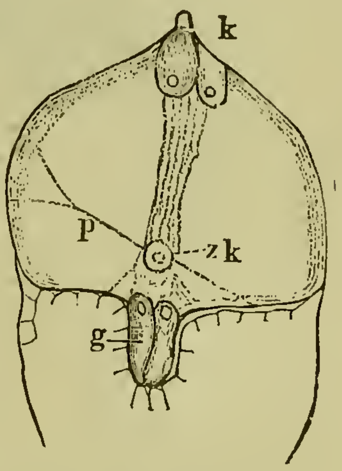


FIG. 360.—Upper part of the nucellus of the ovule of *Crocus* : *p* the embryo-sac with its nucleus *zk* ; *k* the embryonic vesicles ; *g* the antipodal cells. (× 75).

termed the *synergidæ*; they are surrounded by a protoplasmic membrane, but not by a coat of cellulose. In some cases

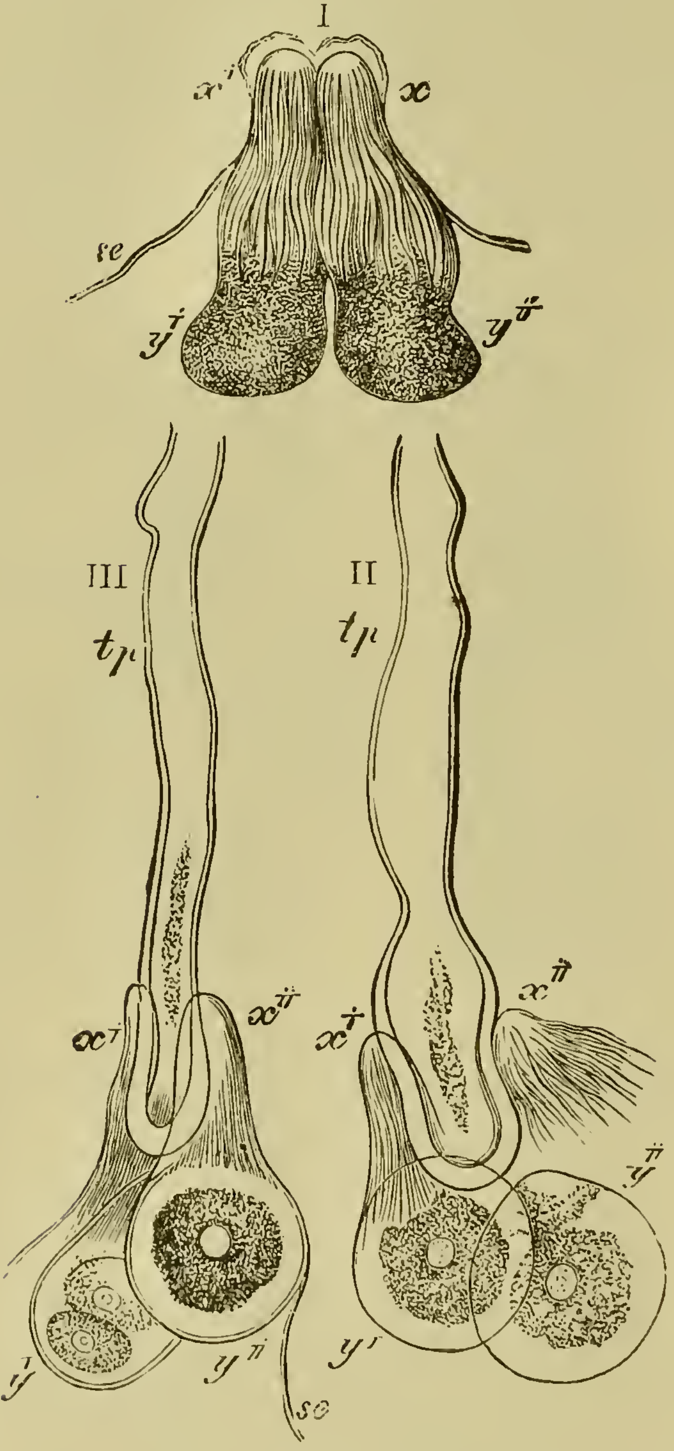


Fig. 361.—The process of fertilisation in *Gladiolus segetum*: I. the two embryonic vesicles at the apex of the embryo-sac; x' x'' the filiform apparatus; y' y'' the balls of protoplasm ready for fertilisation; *se* the wall of the embryo-sac. II. a pollen-tube *tp* which has just fertilised the two embryonic vesicles in contact with it; the cell-walls which surround the balls of protoplasm are still very thin. III. a somewhat later stage; the cell-walls are thicker; the fertilised vesicle y' is beginning to develope and to divide into two. (× 400.)

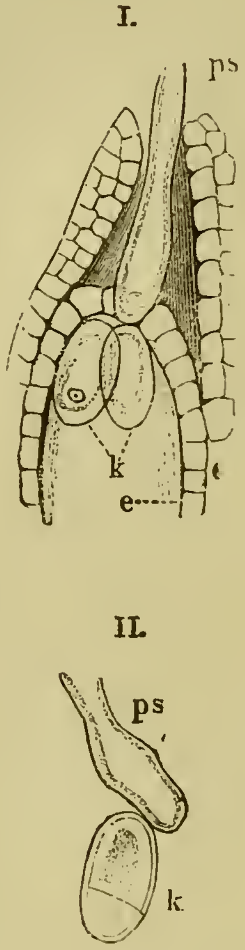


Fig. 362. — Fertilisation of *Canna*: I. apex of the embryo-sac *e* at the time when the pollen tube *ps* has just come into contact with the embryonic vesicles *k*; II. fertilised embryonic vesicle separated. (× 200.)

the elongated superior ends of these cells present a longitudinal striation, termed the *filiform apparatus* (Fig. 361 I. *x′ x″*), and supposed by Schacht to play an essential part in impregnation. The third of the germinal vesicles, lower down and somewhat lateral in position, is the *oosphere* or *ovum-cell*, and its nucleus is the sister-nucleus to the polar nuclei which coalesce to form the permanent nucleus of the embryo-sac. Occasionally two of the embryonic vesicles are fertilised and produce perfect embryos, affording instances of *polyembryony.*]

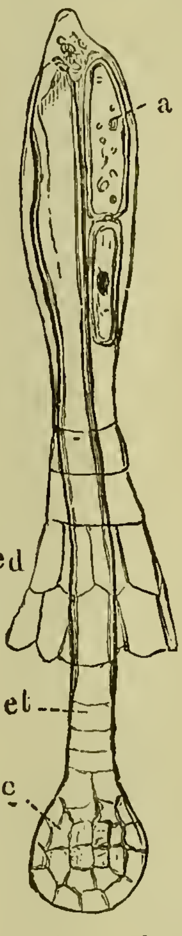


FIG. 363. — Formation of the embryo of *Heliotropium* : *ed* endosperm ; *et* suspensor ; *e* rudiment of the embryo, its enveloping membrane being already formed ; *a* cells developed out of the other embryonic vesicle.

Of the numerous pollen-tubes which, as a rule, reach the ovule, one penetrates through the micropyle, and reaches the embryo-sac either directly or by forcing aside the tissue which still lies above it. At the apex of the embryo-sac the pollen-tube comes into contact with the embryonic vesicles, and fertilises one of them, the oosphere (Figs. 361, 362), the others, as a rule, entirely disappearing. Immediately after fertilisation, the fertilised embryonic vesicle, which was before naked, becomes clothed with a cell-wall of cellulose, and begins at once to develope. It is now known as the *oosperm.* This divides, at first, into two cells, the upper one of which becomes the *suspensor* or *pro-embryo*, while the lower one developes, by frequent division and growth, into the *embryo* (Fig. 363). The suspensor is sometimes longer, as in Borragineæ, Cruciferæ, Labiatæ, and Scrophulariaceæ, or shorter, as in Polygonaceæ, and in *Potamogeton* consists of a single globular cell ; occasionally it is composed of pairs of cells lying side by side ; sometimes it is entirely wanting. In the Leguminosæ each cell of the suspensor frequently contains several nuclei, sometimes as many as thirty.

The radicular end of the embryo is always developed first on the suspensor, and hence the radicle of the mature embryo is almost always turned towards the micropyle. During its growth the embryo is almost always, except in Orchideæ, nourished by a tissue developed in the embryo-sac (Fig. 364), and termed the *albumen* or *endosperm.* The formation of this tissue, which takes place by free-cell formation, commences while the suspensor is developing. When the embryo-sac has ceased to grow, the endosperm-cells become vacuolated, and invested by walls of cellulose. In this condition a communication has been observed between the contents of adjacent cells by protoplasmic threads passing through the cell-walls. The endosperm is occasionally reduced to only a single row of cells, and in *Canna* is said to be entirely wanting. In some very large embryo-sacs the centre is filled with a watery fluid, forming the 'milk' of the cocoa-nut. The function of the endosperm is to supply the growing embryo with nutriment, though some is also derived from the nucellus through the suspensor. In some cases the endosperm is thus ultimately entirely consumed, and the mature seed is then said to be *exalbuminous* ; if a portion of it is left, it is *albuminous.* When a portion still remains of the tissue of the nucellus itself, this is called the *perisperm.* Cannaceæ have a perisperm, but no endosperm, while Nymphæaceæ (Fig. 365) have both. The cells of these tissues are finally filled with a quantity of nutrient substances of all kinds, which serve for the nutrition of the young plant when germinating.

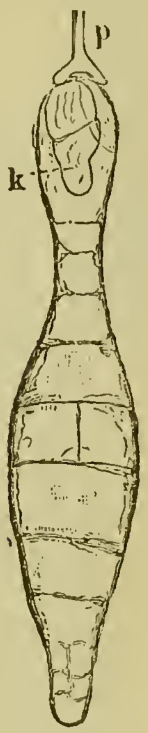


Fig. 364.—Separated embryo-sac of *Heliotropium*, the endosperm consisting of a long row of cells : one of the cells in the middle has already divided transversely ; *p* pollen-tube ; *k* rudiment of the embryo.

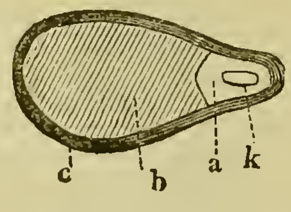


Fig. 365. — Longitudinal section through a seed of *Nymphæa* : *c* testa ; *b* perisperm ; *a* endosperm ; *k* embryo.

The processes concerned in fertilisation and the formation of the embryo in Gymnosperms (Coniferæ and Cycadeæ) differ somewhat from that now described. The pollen-grain, always carried by the wind, falls directly upon the micropyle of the ovule, the pollen-tube being developed from one of its daughter-cells (Fig. 366). The embryo-sac, at least in Coniferæ, is filled up, even before pollination, with endosperm-cells, which, however, have only a transitory existence. After some weeks, or often only after some months, they are again absorbed, a fresh development of endosperm taking its place. In this latter, towards its apex, are formed, after pollination has taken place, a few cells of larger size than the rest, the *secondary embryo-sacs* or *corpuscules*[1] (Fig. 367), the number of which differs in different genera. After some time each of them splits up by a partition-wall into

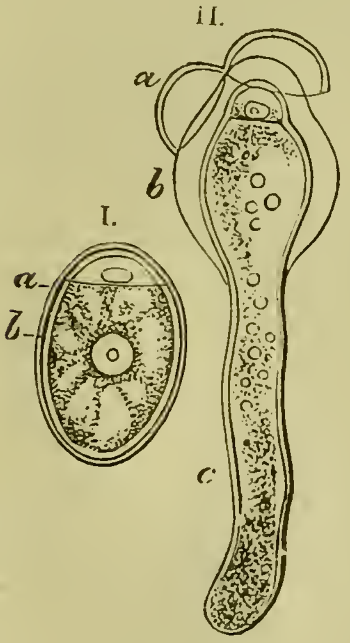


FIG. 366.—Fertilisation of *Cupressus sempervirens* (Coniferæ): I. a pollen-grain with its two cells; *a* extine; *b* intine; II. pollen-grain in which the pollen-tube *c* has been formed. (× 300.)

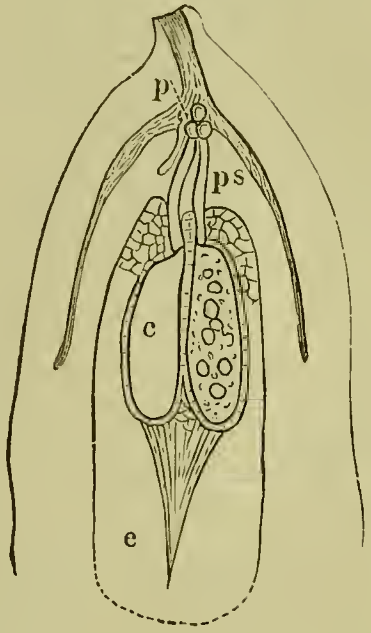


FIG. 367.—Fertilisation of *Abies excelsa*: *p* pollen-grains: *ps* pollen-tubes: *c* two corpuscules in the embryo-sac *e*. (+ 60.)

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[1] Sometimes called *archegonia*, from their resemblance in structure and function to these organs in Vascular Cryptogams, to the central cell of which they are homologous.

two cells, a smaller upper one, the *neck-cell*, and a larger lower one, the *central cell*. The first forms the neck, either remaining simple or splitting up into several contiguous cells. In the central cell is developed a large *oosphere*, which is surrounded by the neighbouring tissue of the endosperm as a peculiar enveloping layer of cells. There are no synergidæ or antipodal cells. At the time of pollination the ovule exudes a drop of viscid fluid. This excites the emission of the pollen-tube, which now advances to the corpuscules, becomes closely applied to several of them, or penetrates into the neck of a single one, often even into the central cell, and transfers its contents to the oosphere. The oosphere now breaks up in its lower part, in Cupressineæ, into several cells lying one over another ; or, in Abietineæ, a layer of cells is developed there by repeated cell-divisions. These cells divide further, and form the *pro-embryos*, which in the course of their development break through the embryo-sac, an embryo being formed at the lower end of each. As a rule only one rudimentary embryo in each ovule attains perfection.

The *germination* of many seeds takes place as soon as they escape from the fruit and attain favourable conditions of moisture and warmth ; in others, on the contrary, a period of rest seems to be necessary in order for them to ripen, *i.e.* to become capable of germination, by slow changes, probably of a chemical nature. The radicle of a seed of the willow pierces the testa as soon as twelve hours after sowing ; and if it is allowed to remain dry for only twelve days it loses its capacity for germination. The seeds of the elm, poplar, coffee, and many Lauraceæ also germinate only when they have been kept fresh and have not dried up ; while that of the mistletoe often germinates even while still inside the fruit. Fresh seeds in general germinate more quickly and easily than old ones. Seeds which contain starch may, on the contrary, retain their power of germination for many years, if kept dry. The temperature rises during the germination of seeds, in consequence of the absorption of water and formation of carbon dioxide.

In order for germination to take place, it is essential that the temperature should fluctuate only between certain limits, which, as might be expected, vary greatly in the case of different plants. In the case of wheat, for example, the lower and upper limits are 5° and 43° C.; for barley 5° and 36°–37·5° C.; for maize 15° and 46·2° C. The seedling derives its earliest nutriment from the seed, and especially from the cotyledons, or, when there is endosperm, from it also through the medium of the cotyledons. The radicle first emerges from the seed, and after it the plumule. The *radicle* is, in Dicotyledonous plants, a direct prolongation of the axis of the embryo, and, therefore, a tap-root; while in Monocotyledons, on the other hand, the radicular end of the embryo never becomes a primary root; a number of adventitious roots are, on the contrary, developed (see Fig. 105, p. 74), and it is only rarely (Fig. 368) that the radicular end of the embryo elongates into a protuberance which soon perishes. In respect to the cotyledons also, there are two modes of germination. They either remain beneath the soil still enclosed in the testa, (Fig. 369), or they rise above ground and throw off the testa (Fig. 370). The single cotyledon of Monocotyledons almost always remains beneath the surface, as also do those of the oat

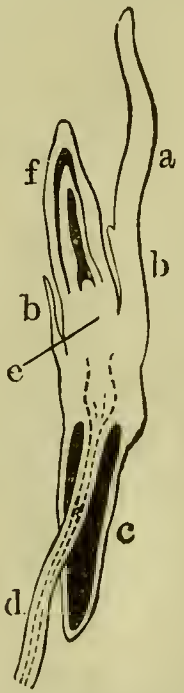

Fig. 368.—Germination of the oat; *a* cotyledon; *e* axis of the embryo; *d* radicle; *f* plumule (× 6).

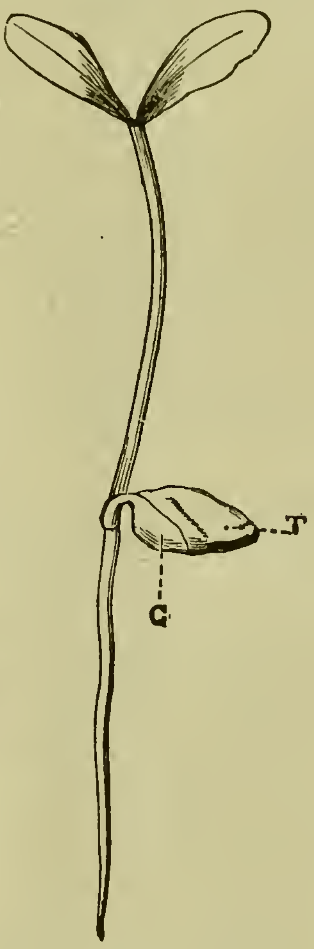

Fig. 369. — Germinating seed of orange, its cotyledons C remaining beneath the soil, and only slightly emerging from the testa T.

and sweet chestnut, while in other Dicotyledons, as the beech, birch, and lime, they emerge from the soil. The *plumule* of Monocotyledons consists of superimposed leaves of a sheath-like or cornet-like character (Fig. 368); while in Dicotyledons the cotyledons, when they separate, are green and leaf-like.

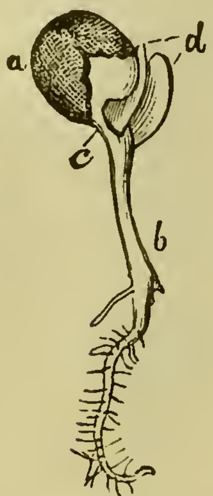

FIG. 370.—Germinating seed of cabbage; *b* axis; *c*, *d* the two cotyledons which have risen above the soil, the testa *a* not being yet completely thrown off (× 4).

In all modes of reproduction the properties of the parent plant are transmitted to its descendants. When reproduction is effected by asexual cells, this is altogether the case; but when the reproductive cells are fertilised oospheres, only so far as to maintain the character of the *species*. When the fertilising (male) and the fertilised (female) cell are derived from plants which belong to different species, fertilisation can take place only if the two species are very nearly related to one another. An individual resulting from impregnation of this character is a *hybrid*; and it is determined by a number of circumstances, some of which are still unknown, which of the two parent species the hybrid most nearly resembles. Hybrids resulting in this manner from the crossing of two species not unfrequently occur in nature; but their power of propagation is commonly defective, and they are often altogether infertile.

In systematic botany hybrids are distinguished by names compounded of those of their parent-species, the name being placed first of the one which it most resembles. Thus between *Mentha rotundifolia* and *M. sylvestris*, two hybrids are known, *M. rotundifolio-sylvestris* and *M. sylvestri-rotundifolia*, the former of which most nearly resembles *M. rotundifolia*, the later *M. sylvestris*.[1]

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[1] [A more usual and preferable practice is to place the name of the male parent first, of the female parent last. Thus *Mentha rotundifolio-sylvestris* would be the result of the fertilisation of *M. sylvestris* by *M.*

Fertilisation is easier between different varieties of the same species than between different species, the result being in this case termed a *variety-hybrid.* The stamens are often replaced in them by petals, thus forming what are called double sterile flowers, on which account they are not generally so well calculated for propagation as species-hybrids.

It is easily understood that agriculture, and especially horticulture, takes advantage of these peculiarities in order to call into existence varieties of plants cultivated for their usefulness or their beauty.

The subject of fertilisation is incomplete without a description of the mode of reproduction of Cryptogams by means of oospheres. But as an account of the very numerous modifications of this process must necessarily be given under the separate classes, the whole subject is deferred till the section on classification.

PHENOMENA OF MOVEMENT.

Motion is an essential condition of life. The plant, therefore, like the animal, exhibits phenomena of motion ; but since the former finds conditions suitable for existence on all sides, these phenomena are in general less strongly manifested than in the case of the latter. It is not necessary here to allude to those movements of a passive character which the plant performs under the influence of wind or wave, or when bent to the ground beneath the weight of its fruit, rising again subsequently to an erect position ; in short, to those movements which are imparted to it by the obvious action of mechanical forces. Those only will be referred to which are inseparable from life, and are a direct result of the vital processes.

It is impossible to give a minute account of all these various phenomena of movement ; but they will at least be made somewhat more

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rotundifolia, *M. sylvestri-rotundifolia* the result of the fertilisation of *M. rotundifolia* by *M. sylvestris.*—Ed.]

intelligible by observing those forces which are inherent in plants from the mode of their construction out of cells, as well as from the molecular structure of their organised parts.

Chemical processes in the interior of the growing structure are always connected with growth by intussusception, as this process has already been described (see p. 15). Thus the nutrient fluid which forces its way into the cells from without by the action of osmose, contains, it is true, material for the formation of molecules of a definite chemical composition ; but this material is chemically different from the molecules which it nourishes. Thus starch-grains are produced out of a fluid which does not contain any starch in solution ; the cell-wall is formed by the secretion of substances out of the protoplasm which are not dissolved cellulose ; the colouring matter of the chlorophyll is first formed in the interior of the chlorophyll-bodies, &c. Growth by intussusception is therefore connected not only with a continual disturbance of molecular equilibrium, but also with chemical processes in the interior of the growing structure. Chemical combinations of the most various character must therefore take place between the molecules of the organised body, and act and react upon one another.

It is certain that growth can only take place so long as the growing parts of the cell are permeated by atmospheric air, and that the oxygen of the atmosphere decomposes the compounds within the organised structure.[1] The formation and evolution of carbon dioxide is therefore a necessary accompaniment of growth ; and not only is the equilibrium of chemical forces thus being continually disturbed, but heat is also necessarily produced, and electrical action may perhaps also come into play.

By the chemical processes which have been partially described in detail when treating of nutrition, by the influence of heat, and perhaps also by electrical action, forces of considerable magnitude are set free in the interior of the plant, which set in motion its smallest particles (atoms or molecules), and thus represent a definite amount of work within the growing organised body, which is probably often enormous.[2] And herein we have an essential characteristic of all organisation and of life, *viz.* that organised structures are capable of a continual internal change ; and that so long as they are in contact with water and with atmospheric air, only a portion of their forces can be in equilibrium in their interior ; in short, that they are in continual internal movement. The whole organism forms, therefore, a framework, between and in the molecules of which forces are constantly being set free by chemical changes, which forces again occasion further changes. This is essentially dependent on the peculiar molecular structure which allows that at every point in the interior substances penetrate from without and are absorbed in the liquid or gaseous state, and can again be expelled. This internal changeableness attains its highest grade in the chlorophyll-bodies and the protoplasm. In the former, chemical changes take place with great energy and force under the influence of light, such as the formation of the green colouring matter and of starch ; while the absence of light at once sets up other chemical processes, which terminate only with the complete destruction of the whole of the chlorophyll-body.

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[1] See p. 167, on the process of respiration.

[2] The temperature of dry grains of starch, when they absorb water of the same temperature, rises 2° or 3° C. ; while boiling water is only raised in temperature about 0·078° C. by a pressure of ten atmospheres. Since, as experiment has shown, the rise in temperature on absorption depends on an increase in density of the water, these statements will give some idea of the enormous force with which the absorption takes place.

Besides the chemical and physical forces, others are also set free in plants by the mutual action on one another of their cells, which are manifested in a *tension* of the tissues or of the cells with respect to one another.

Every part of the plant consists of external and internal layers whose growth proceeds, at least for a time, with a different rapidity in the same direction. A necessary consequence of this unequal energy of growth is a corresponding tension of the different layers with respect to one another ; because those which are growing more quickly are prevented from expanding as much as their growth requires, and hence exercise a pressure on the layers that grow more slowly, which these seek to counteract by their elasticity. Such tensions of the layers caused by unequal growth may still continue after growth has ceased ; but they may also be destroyed by a change in the relative rates of growth. The existence and the nature of the tension can be easily shown by separating the layers from one another ; those which had grown more quickly, and were therefore previously compressed, will expand ; those which had grown more slowly and which were therefore previously stretched to more than their natural length, will now contract elastically; the former become longer, the latter shorter, than before their separation. A partial separation of the tissues is often sufficient to show this. If, for example, any rapidly growing stem is cut longitudinally into four pieces cross-wise, the pieces curve concavely outwards and convexly on their inner side, in consequence of the internal layers extending while the outer layers contract. These tensions caused by the unequal growth in length of different layers of tissue act chiefly in the direction of the axis of the growing structure, and are therefore called *longitudinal tensions*. But when, after growth in length has ceased, a permanent increase in thickness takes place, as for instance in the case of the stems of forest-trees, then this increase in thickness is accompanied by a *transverse tension* in the radial and tangential directions. This is generally caused by the cortical tissue growing more slowly than the wood; and this, as has already been shown, causes the bark to become too small for the wood, and hence to compress it considerably; no inconsiderable pressure being exerted, on the other hand, by the wood on the bark. This can be easily shown by stripping a ring of bark from a stem, and slitting it up one side, when it contracts, and will no longer enclose the wood, its edges gaping apart.

Tensions of different layers do not occur only in tissues, but also in the cell-walls of individual cells; and it is then usually the outermost layers of the cell-wall which are stretched by the inner ones, while these latter are correspondingly compressed by the elasticity of the outer layers.

The *turgidity* of the cell, or the pressure exercised by the cell-sap on the enveloping cell-wall, must be carefully distinguished from the tension of the layers of tissue. Turgidity is caused by the substances dissolved in the cell-sap attracting the water which surrounds the cell by the force of endosmose; the water accumulates within the cell-cavity by endosmotic attraction, and, exerting a pressure on the inside of the cell-wall, places it in a condition of greater or less tension.

The final result of the growth of the cell-wall caused by the various forces enumerated—its extensibility and elasticity, and the turgidity of the cell—is a measure of the rigidity or flaccidity of the plant or part of the plant. The total tension, for instance, is diminished, and the part becomes more flexible, when the turgidity decreases from loss of water, or when the elasticity of the stretched cell-walls diminishes, or when the cell-walls become more extensible, or, finally, when the inequality of the growth of the different layers of tissue diminishes. When a change of this kind takes place on all sides, the part of the plant will become shorter or longer according as the tension diminishes or increases; but if it takes place on one side only, a corresponding curvature is caused.

To complete the account of the forces at work in the plant, we must add to those already mentioned, which are peculiar to the molecular structure of their organised parts and to the phenomena of tension, others which are set free by the movement of water and of gases within the plant. Sufficient reference has already been made to the former under the head of nutrition. The latter class of movements is easily explained by the continual interchange, through the medium of the stomata, of the gases formed in the intercellular spaces with the external air, and by the fact that in growing plants gases are continually passing in and out of the cells by the force of diffusion. A large number of very remarkable movements of plants and of parts of plants are at least to some extent explained by the co-operation of these forces; but a large number of others still require further investigation.

The wonderful properties of protoplasm, to which attention has already been directed, culminate in its spontaneous motility, in its capacity of assuming different forms, of changing its outline and its internal condition, and of thus calling into activity internal forces without any corresponding impulses being observed to act upon it from without. Good examples of this capacity are afforded by the *circulation* which occurs in the filaments of the stamens of *Tradescantia*, the stinging-hairs of the nettle, &c. The movement of the protoplasm in these cells is apparently not subject to any definite law, sometimes advancing, sometimes retreating, and sometimes suddenly ceasing. The protoplasm often makes for itself new courses in the cell-sap; but its motion appears to be dependent on the nucleus, round which it always flows, and often carries it along with it. When the protoplasm within a cell possesses this power of motility, it is not extraordinary that cells destitute of a cell-wall (primordial cells) should have the power of moving from place to place; and, in fact, the naked primordial cells of the Myxomycetes, which are termed *plasmodia*, are endowed with the faculty of moving like an animal, and even, in the case of *Æthalium*—the so-called 'flowers of tan'—of creeping to the distance or height of several feet, as if endowed with voluntary power. It is, therefore, not to be wondered at that even till quite recently these organisms were considered to be animals; while at present they are assigned to an abnormal section of Fungi, to which class they are allied by the mode of formation of their spores. The rapidity of these 'streaming' movements varies greatly; the maximum appears to occur in *Didymium Serpula*, where a rate of 10 millimetres in a minute has been observed.

The *antherozoids* and *zoospores* (swarmspores) of many Cryptogams were long considered to belong to the animal kingdom; and they actually show so close a resemblance to animals that they might well have been described as plants at the moment of their transformation into animals. The zoospores of Algæ are particles of protoplasm which break through the walls of the cells in which they are formed, and swim about for a time in water like animals. It is only since it has been ascertained that they give birth, after a shorter or longer period of rest, to a plant of the same species as that from which they sprang, that their vegetable nature has been absolutely determined. The internal forces by which these zoospores (Fig. 386, p. 254), and the antherozoids (Fig. 371) which are endowed with motion of a similar nature, are enabled to perform their movements, are still unknown; but they are certainly connected with the vibratile cilia, or minute threads of protoplasm of different lengths and variable number, the vibrations of which set the body in motion. But it must be admitted to be a most wonderful contrivance for the maintenance and propagation of a number of vegetable organisms.

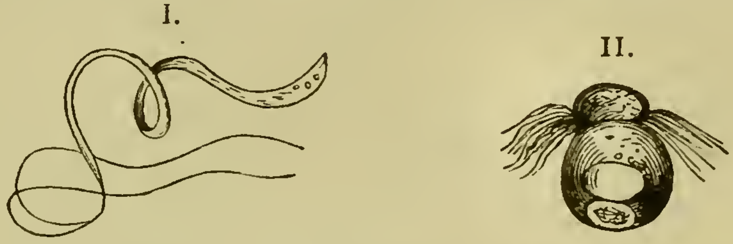

Fig. 371.—Antherozoids: I. of *Nitella syncarpa* (Characeæ, × 500); II. of *Œdogonium gemelliparum* (Algæ, × 800).

Neither zoospores nor antherozoids are provided with a cell-wall—or, at all events, with only an extremely delicate one—during their period of motility. Still more remarkable than these must, therefore, be considered the movements of the Diatomaceæ, [Desmidieæ], Oscillatorieæ, Bacteria, and some other organisms which are enclosed in a complete cell-wall, or even in a hard siliceous coating, as in the case of the Diatomaceæ. The Oscillatorieæ consist of long filaments which often oscillate rapidly; and the Spirulineæ are filaments of similar form which coil about in a great variety of ways. The cause of their movements has not been ascertained.

Circumnutation is the term given to those curvatures which cause parts of plants that are growing in length to assume successively different directions without any apparent external cause. Examples are furnished by the flowering scapes of the onion, which, before they attain their ultimate length, bend slowly first to one side and then to another; or, still better, by climbing stems. In these, such as the hop and the scarlet-runner, the first internodes do not twine; but when the apex of the stem hangs down in consequence of its weight, it begins to revolve in a circle, and thus to approach the support which it afterwards embraces. The earlier coils are hence looser than the later ones, which embrace the support more closely. These curvatures of circumnutation appear, in general, to take place at the spots where the tension of the tissues is the greatest, and to be caused by the growth in length being greatest first on one and then on the other side. The twining of tendrils is due to a similar property of circumnutation, combined with a sensitiveness to be mentioned hereafter.

Parts of plants which are growing in length sometimes become, by long-continued close contact with a solid body, firmly attached or adherent to it. Instances are afforded in the adhesion of pollen tubes to the stigmatic hairs and to the internal wall of the ovary; and in the climbing and turning of the tendrils of many plants round slender supports.

Tissues in a state of tension become relaxed by concussion. Parts of a great number of plants, when in a state of active growth, undergo a diminution of the elasticity of their tense tissues by violent shaking, repeated bending, a blow on one side, or sometimes even simply by stretching, the tissues thus becoming flaccid, and the parts becoming elongated and bent. These facts can easily be established by experiment, very clearly by simple observation of rapidly growing plants shaken by violent winds, when, though apparently injured, they are not generally so in reality. In other cases of a similar kind the extensibility of the parenchyma is diminished, and a flaccidity, shortening, and curvature of the organs occasioned. These changes are probably the cause of the movements of *irritability*, as it is termed, of some leaves; although these phenomena may also be due to other causes, such as electrical shocks or currents. The most remarkable instance occurs in the leaves of the sensitive plant, *Mimosa pudica*. The bipinnate leaves of this plant are united to the stem by an articulation, as also are the four pinnæ and the separate leaflets to their petioles (see Fig. 517, p. 403). The primary petiole has the greatest scope for movement, since it can rise or fall to the extent of a semicircle. The pinnæ move upwards and laterally, so that they lie upon one another like parts of a fan. The secondary pinnules move upwards, and close up like the wings of a butterfly at rest. The sensitive plant closes its leaves spontaneously in the evening, and also in the day-time when excited by any irritation. This irritability is only manifested when the temperature of the surrounding air is above 15° C.; it is still weak between 16° and 18°, and appears to reach its maximum at 30° C. At that temperature the plant is so sensitive that the movement is communicated to a number of leaflets almost simultaneously; while, when the sensitiveness is less, the movement advances regularly from the irritated spot. The closed leaflets again assume their normal position when the irritation ceases, if it has not been too strong and consequently had an injurious effect; and this takes place sooner or later according to the vigour of the plant, commencing sometimes in as short a time as five minutes. Poisons often kill the sensitive plant; anæsthetics, such as ether or chloroform, usually temporarily paralyse it; and constant repetition of the irritation is followed by a diminution for a time of its sensitiveness. It is probable that the tissue of the lower side of the pulvinus, or mass of succulent tissue found at the articulation, contracts after irritation such as that produced by simple contact, its cells losing a large portion of their cell-sap, and thus becoming less turgid, and giving space for the expansion of the tissue of the upper side. A depression is thus caused of the leaf which is attached to the articulation; and this is not counteracted by the vascular bundles in the pulvinus in consequence of their flexibility. A fresh flow of sap into the part of the tissue which was previously emptied then causes a fresh elevation of the leaf. [There can be little doubt that the motility of the leaves of *Mimosa* is connected with the continuity of protoplasm recently discovered in the cells of the motile organ.]

Venus's fly-trap, *Dionæa muscipula* (Fig. 372), manifests a similar irritability. On each half of the upper side of the leaf, through which passes a strong mid-rib, are three small bristles; and when one of these bristles is irritated, the two halves of the leaf close together, and remain closed until the irritation has ceased. If, therefore, a small insect, such as a fly, settles upon the leaf, it becomes shut in, and is retained between the halves of the leaf until it is dead and no longer exercises any irritation upon it. One of the best examples of irritability is furnished by the various species of *Drosera* or sundew. The margin and upper side of the leaf are furnished with numerous red glandular hairs or 'tentacles.' The club-shaped head of these hairs exudes a viscid fluid, in which any insect that alights on the leaf becomes imprisoned. As soon as the insect is captured, the tentacles begin to bend over from all sides towards it, until it is completely enclosed by the club-shaped heads of all the tentacles of the leaf. There can be no doubt that the object of the movements, both in this case and in that of *Dionæa*, is the digestion of the soft portions of the body of the insect by means of special glands, since the movements are accompanied by the excretion of a digestive ferment identical with animal pepsin; and experiments have proved that plants provided with food of this nature flourish better and produce a larger number of seeds than those which derive their nutriment through the root only. Any substance con-

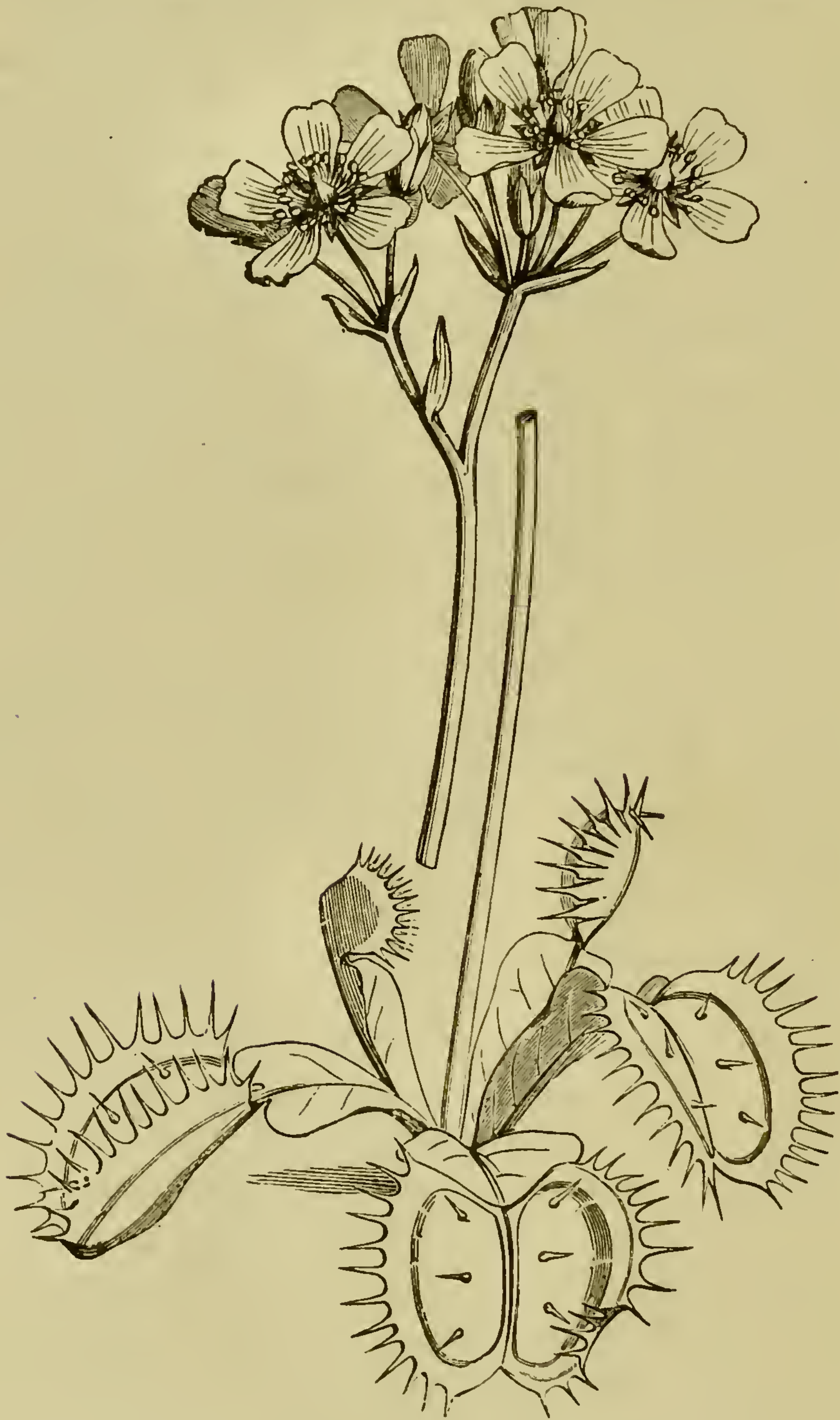

FIG. 372.—Venus's fly-trap, *Dionæa muscipula* (natural size).

taining nitrogen serves to stimulate the movements of the tentacles of *Drosera*.

The stamens of many Compositæ, such as *Centaurea*, contract when irritated before pollination. The stamens of *Berberis*, when touched on the inner side, spring violently against the pistil, and place their anthers in contact with the stigma. The stamens of the grass of Parnassus, *Parnassia palustris*, lengthen in succession, and place their anthers on the stigma.

The stigmas of some plants, as *Bignonia*, *Gratiola*, *Martinia*, [*Mimulus*], &c., which are expanded at the time of pollination, close on contact. A similar phenomenon is exhibited by the stigmas of *Torenia asiatica*, which close immediately after pollination, open again in a few days, but are then insensitive to further contact. Movements of this nature are all closely connected with the sustenance and propagation of the plant.

Closely connected with these movements are those belonging to *tendrils* and tendril-like organs. In their early state, before they have coiled up backwards or have clung to a support, these organs are sensitive to simple and slight contact or to very light rubbing, the side on which they are touched becoming, after some minutes, concavely curved. The bent tendril subsequently straightens itself, and is then again irritable. Bent tendrils are sensitive only on the concave side.

Those parts of plants in which there is generally a tension of the tissues exhibit a constant increase and decrease in the degree of tension. Under the ordinary conditions of life, in which plants are subject to the alternation of day and night, the intensity of the tension declines from morning till noon, and rises during the night, attaining its maximum in the morning. The most beautiful illustration of a movement of this nature, and the most independent of external influence, is furnished by the telegraph-plant, *Desmodium gyrans*, a southern Asiatic shrub. The leaves of this plant are trifoliolate, the central and largest of the three leaflets moving only in sunshine, and assuming besides different positions by day and by night; while the lateral leaflets, which are about one-sixth the size of the middle one, perform almost uninterrupted oscillations whenever the temperature exceeds 22° C., their apices describing an ellipse. These oscillations, which are often very active, so as to recur several times in a minute, do not, however, proceed uninterruptedly, but spasmodically, as if the plant were continually acquiring new strength, or overcoming an obstacle. Other species of the same genus show similar but less active movements. These movements always result from a periodical alternate lengthening and shortening, first of one, then of the other side of the motile organ. Similar movements, but of less intensity, are exhibited by the leaflets of the red clover, the wood-sorrel, and many other plants. Those of the red clover alter their position by as much as 90° in the course of two or three hours, when placed in the dark.

Periodical movements are manifested in many other plants, especially in a strong curving upwards and downwards of the part, and then bring about what are commonly known as the *diurnal* and *nocturnal*, or waking and sleeping positions. These phenomena are exhibited especially in the trifoliolate and pinnate leaves of many Leguminosæ and Oxalideæ, which at night depress their common petioles or the laminæ of the leaflets, the latter lying or closing upon one another in a variety of ways. The flowers of some other plants, as, for instance, *Hemerocallis*, close regularly in the evening, and open in the morning. Others, again, like the marigold, vary according to the weather; in clear, dry weather, they expand their capitula between six and eight in the morning, and close them between four and six in the afternoon; whilst when the sky is perfectly cloudy, or in rainy weather, they remain altogether closed.

These periodical movements are often confounded with the curvatures of periodically motile organs, caused by their exposure alternately to a greater and less intensity of light. Thus, for example, sudden removal of light causes the leaflets of the bean to be depressed, those of the clover to be bent sideways; while sudden exposure to light, or increase in its intensity, produces the opposite effect. The leaves of *Oxalis*, on the other hand, assume the nocturnal position in direct sunlight. Curvatures of this nature, caused by light, are called *paratonic*.

While paratonic curvatures are caused only by the presence or absence of light, and are independent of the direction in which the light falls upon the plant, the contrary is the case with *heliotropic* curvatures, which occur only on the side from which the strongest illumination comes. If the side which faces the source of light curves concavely, the effort after light, or *heliotropism*, is said to be *positive*; if convexly, it is *negative*. The former phenomenon is exhibited by most internodes of erect stems which are in active growth, and especially by petioles, which by this means place the surface of the leaf in such a position that it will receive the greatest possible amount of light. It may be seen very strikingly in plants grown in a window, which at length become quite crooked, from their young parts which face the light becoming rigid in this position. Comparatively few parts of plants are negatively heliotropic; examples occur in the tendrils of the grape-vine, and in older branches of the ivy, which by this means become firmly adpressed to their support. Heliotropic curvature does not contract the part of the plant; but in positive heliotropism the shaded side elongates from more active growth more rapidly than the side which faces the light; [in negative heliotropism the reverse].

One other phenomenon must be mentioned in this connection, *viz.*, that known as *geotropism*, or the tendency to grow away from or towards the centre of the earth. Parts of plants which are still growing in length tend to place themselves in such a position that the direction of their growth is vertical, or coincides with the direction of the force of gravitation. If the growing part consists of tissues in which there is no tension, as is the case with roots, it will simply follow the direction of gravitation, and its apex will direct itself vertically downwards. But when the growing part consists of layers of tissue in a state of tension, a change takes place in the tension of the tissues and in the direction of growth, which causes the under side of the curved part to grow more vigorously than the upper side, and consequently tends to force the apex upwards. The erect growth of most stems is a result of this force of geotropism.

GENERAL CONDITIONS OF PLANT-LIFE.[1]

Very little is at present known with regard to the general bearing of plants as respects *heat*; for example, with regard to their power of conducting heat, or to the changes in volume of masses of tissue and individual cells through the influence of temperature; but somewhat more on the influence of different degrees of temperature on the various vital phenomena of plants. On this point the following important laws have been established :—All functions of the organs of a plant are brought into play only when the temperature rises to a certain height above the freezing-point of the sap. When the temperature begins to rise above this lower limit, the functions begin to be exercised with an increasingly greater energy, until at a certain height the point of the greatest vital activity is attained. With a further increase of temperature above this point, both the rapidity and the energy of the functions again decrease, until, at length, they completely cease at a definite maximum of temperature, which can apparently never be permanently higher than 50° C.

Beneath a covering of snow, or at a temperature below zero C., scarcely anything grows. The few perennial plants which blossom with us in the winter, as the Christmas rose and hepatica, freeze when the temperature falls below zero at any stage of their growth, which begins again as soon as they thaw. The extraordinarily rapid growth of Alpine and Arctic plants in spring depends on a long anterior development of their floral organs in the preceding autumn. The green sods and the great number of leafy plants which appear as soon as snow melts, only show that the number of evergreen plants is larger than is generally supposed. Growth is entirely dependent on the temperature of the atmosphere; hence the blooming of willows and rhododendrons whose roots and stems are still frozen, as well as the development of the so-called 'red snow,' *Palmella nivalis*, on the surface of the snow. Neither the lowest nor the highest temperature at which plants can exist has yet been determined. It would appear, however, that water must not be above 40° C. for plants to be able to live in it. Plants living in the air, on the other hand, will endure for some time a temperature of from 48° to 49° C.; at 51° they are killed in from 10 to 30 minutes.[1]

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[1] This section is taken in the main from Sachs's *Textbook of Botany*, Book III., chap. iii.

The growth of the embryo at the expense of the reserve-materials stored up in it, begins, with wheat and barley, at about 5° C.; with the scarlet-runner and maize at 9°·4; with the pumpkin, *Cucurbita Pepo*, not below 13°·7 C. But when the reserve-materials have been consumed, a higher temperature is apparently always necessary to enable growth to proceed by means of freshly assimilated material. The highest temperature at which germination can take place is about 42° C. for the scarlet-runner, maize, and pumpkin; 37° to 38° C. for wheat, barley, and peas.

The lowest temperature at which the chlorophyll-bodies turn green is above 6° C. in the scarlet-runner and maize; between 7° and 11° C. for *Pinus pinca*; and the highest at which leaves already formed and still yellow turn green is above 33° C. The cold of winter often occasions a winter-colouring in evergreen plants. This is caused: (1) by a brown colouring, in consequence of a peculiar transformation of the blue-green constituent of chlorophyll, as in Coniferæ and the box; (2) by a red colouring, in consequence of the formation of a red pigment soluble in water and imbedded in balls of tannin, as in *Mahonia*; (3) by a change in colour of the chlorophyll itself by the shifting and collecting into masses of the grains of chlorophyll; this occurs in all plants. A higher temperature restores the normal condition.

The exhalation of oxygen and consequent assimilation begin, in the case of *Potamogeton*, between 10° and 15° C.; in *Vallisneria* above 6° C.

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[1] [A few Algæ of low organisation appear to be able to withstand a temperature of nearly or quite boiling water; as do also some Fungi, *Bacteria*, and fungus-spores.—ED].

The sensitiveness and periodical movements of the leaves of the sensitive plant do not begin till the temperature of the surrounding air exceeds 15° C. ; the rapid periodical movements of the lateral leaflets of the leaf of *Desmodium gyrans* only at a temperature above 22° C. The action of higher temperatures on the sensitiveness of the leaves of *Mimosa* depends on the continuance of the warmth ; in air of 40° C. they become rigid within an hour ; at 45° C. within half an hour ; at 50° C. in a few minutes, but may again become sensitive when the temperature falls. A temperature of 52° C. causes permanent loss of motility and death.

The lower limit of temperature for the motility of the protoplasm in *Nitella syncarpa* is zero ; for the hairs of the pumpkin 10° to 11° C. The upper limit is 37° C. in the former case ; in the latter the current is arrested within two minutes when immersed in water of 46° or 47° C. ; in water above that temperature within a minute ; in the air, exposure to a temperature of 49° or 50° C. for ten minutes does not stop the current.

The absorption of water through the roots is also subject to certain limits of temperature. The roots of the tobacco and pumpkin, for example, do not absorb sufficient water in a moist soil of from 3° to 5° C. to replace the small loss caused by evaporation, the leaves hanging in a flaccid condition in consequence of the cessation of their turgidity.

The rapidity and intensity of the vital functions are not in proportion to the increase of temperature. The rate of growth of the roots of a seedling of maize attains its maximum at 27°·2 C. ; of the pea, wheat, and barley at 22°·8 C. The sensitiveness of the leaves of *Mimosa* reaches its maximum at 30° C.; the rapidity of the movement of the protoplasm in *Nitella syncarpa* at 37° C.

If the limits of temperature mentioned above are passed, the vital functions of the plant may simply come to rest, as is the case with perennial plants during the winter season; or permanent changes are brought about in the plant or in parts of it, resulting in injury or death. The fatal injury inflicted on cells, both by too high a temperature and by freezing, is a consequence of their containing water.

Air-dry peas can resist a temperature of over 70° C. for above an hour without losing their power of germination ; soaked in water for an hour and exposed to a temperature of 53° or 54° C., they are killed. The cause of death may be partly the coagulation of the albuminoids, while the decomposition of the cell-wall is perceptible only at higher temperatures. Air-dry seeds appear to be able to withstand any degree of cold without injury to their power of germination. The winter-buds of woody plants, the cells of which contain a great quantity of reserve-materials but only a small quantity of water, withstand the cold of winter and frequent rapid thawing ; while the succulent leaves at the time of their unfolding in the spring succumb to a slight night-frost. Many plants, such as Lichens, Mosses, Fungi of a leathery texture, the mistletoe, and some others, appear never to freeze ; while, on the other hand, many flowering plants from a southern climate are killed by rapid changes of temperature near the freezing point. Whether the tissue of a plant can be killed simply by the solidifying of the water of its cell-sap into crystals of ice is uncertain ; while, on the other hand, it is unquestionable that in a great number of plants death is caused only by the mode in which the thawing takes place. The same tissue which retains its vitality if thawed slowly after freezing, becomes decomposed if thawed rapidly after exposure to the same degree of cold ; so that death is evidently in this instance the result not of the freezing but of the thawing. Moreover, the lower the temperature at which the freezing took place, the sooner is the plant killed by the freezing as well as by the thawing. A common but not invariable result of the freezing of the cell-sap is that internal cells or layers of tissue are ruptured ; but these internal rupturings do not, as was once supposed, always cause death ; they have as little to do with the destruction of the life of the cells by cold as the splitting of the branches of the trees caused by frost, which, when the temperature falls very low, is produced by the contraction of the bark and outer layers of wood, the crevices again closing when the temperature rises. The phenomena of freezing are, however, at present but imperfectly understood.

The entire life of the plant depends on the action of *light* on the cells which contain chlorophyll, since this action is essential to the formation of new organic compounds out of the absorbed nutrient substances. But when a certain quantity of assimilated substance has been produced under the influence of light, a long series of vegetative processes may be carried on at its expense without any further direct action of light.

The growth of new organs and the metastasis connected with it which takes place in the parts that do not contain chlorophyll, and which is maintained by the process of respiration, is to a certain extent independent of light, as is shown by the germination in the dark of seeds, tubers, and bulbs. But even leafy plants which have accumulated a sufficient quantity of reserve-material in the light, put out shoots, and even flowers and fruits, when placed in the dark. If, for example, the growing end of a branch of a green-leaved plant, such as a pumpkin or *Tropæolum*, is made to grow into an opaque receptacle, the green leaves remaining still exposed to light, the buds will continue to develope in the dark, and new leaves and flowers to be formed which attain their full size and colour, the latter even producing fruits and fertile seeds. It is only rarely that the seclusion from light produces any perceptible effect on the development of the plant; though sometimes the flowers which are produced in the dark have an abnormally light colour. All this takes place at the expense of the food-material conveyed to them through the stem, which had been previously assimilated by the leaves exposed to light. In the same manner the underground parts of parasitic plants, or those otherwise secluded from the influence of light, carry on their existence to a certain extent independent of light; but are nevertheless indirectly dependent upon it, because they are nourished by substances which could only be formed under the influence of light. The earliest development of the plant seems to be even promoted by the absence of light or by shade. Thus, for example, roots are formed on the stems of *Cactus*, *Tropæolum*, &c. which grow in the dark, where they would never be formed in the light. The lower Algæ assimilate in the day-time, and form zoospores in the night, or, when placed in the dark, even in the day-time. The movement of the protoplasm on which the formation of the zoospores depends is not caused directly by the influence of light, but is rather interrupted by it. The direction of the movements of the zoospores stands, however, in some definite relation to light, their anterior end being always turned towards it. It has, nevertheless, been observed in some cases that they have a tendency to collect where there is a medium intensity of light, avoiding both deep shade and bright sunlight. The chlorophyll-bodies enclosed within cells are subject, in some plants, as *Sagittaria sagittæfolia*, to a change of position, being carried by the currents of protoplasm to the region of brightest light. Finally the normal habit of plants is altogether determined by the direct influence of light. The internodes of the stems of bleached or etiolated plants grown in the dark are often elongated to ten or twenty times their ordinary length; while leaves of Dicotyledons and Ferns, which are normally broad and branched, remain, when grown in the dark, remarkably small. Under these circumstances the lamina of the leaf of *Tropæolum* attains scarcely from $\frac{1}{30}$ to $\frac{1}{20}$ of its normal size; the leaves of Ferns do not even unfold, and attain only $\frac{1}{100}$ or even $\frac{1}{1000}$ of their normal superficial development in the light.

White daylight consists of a mixture of rays of light, differing in their colour and their refrangibility; and it might be expected that the action of the different rays on the vital processes of the plant would not be the same. This is illustrated by the accompanying diagram (Fig. 373).

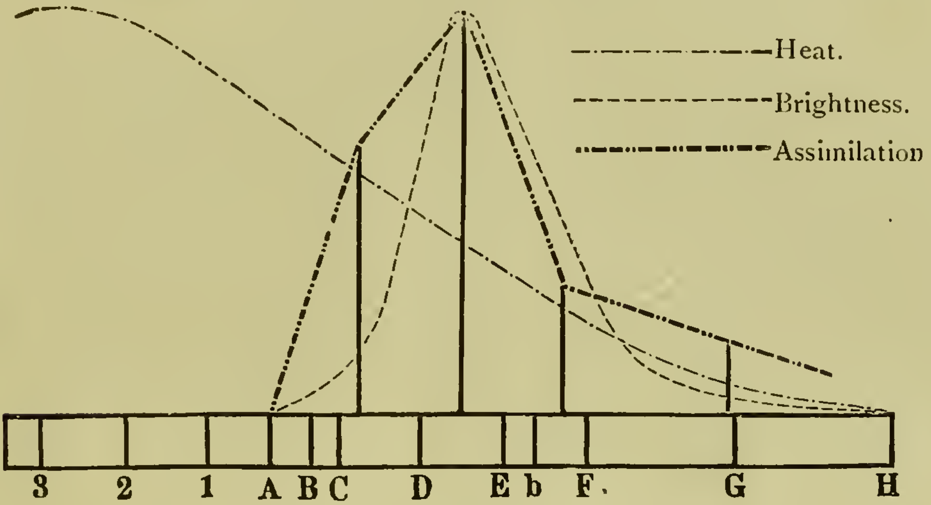

FIG. 373.—Diagrammatic representation of the efficacy of rays of light of different refrangibility in causing evolution of oxygen, compared with their brightness and heating power. The solar spectrum A H serves as a base on which Fraunhofer's lines are indicated; A and B lie in the red light, C on the border of the orange, D in the yellow, E in the green, F in the blue on the border of the green, G on the border of the indigo and violet, H in the violet. The height of the three curves, of Heat, Brightness, and Assimilation, at any point, represents the intensity of the action. Thus assimilation is still slight at G on the border of the violet and indigo, and attains its maximum between D and E on the border of the yellow and green, then diminishing, and ceasing at A on the border of the red light. It is seen that the process of assimilation nearly coincides with the subjective brightness as shown in the colours of the spectrum, while the curve of heating power takes a totally different course and attains its maximum at a point where the eye is unable to perceive any light, and where no process of assimilation goes on in the plant.

The most important chemical process in the plant, the decomposition of carbon dioxide in the cells which contain chlorophyll and the elimination of oxygen resulting from it, proceeds almost as energetically as in white daylight, in a mixture of orange, yellow, and green light which acts only slightly and very slowly on photographic paper. Blue, violet, and the ultra-violet rays, on the contrary, which at once colour photographic paper a deep brown, have no or very little effect on the elimination of oxygen.[1] The same relationship towards light has been shown to exist in the formation of starch in the grains of chlorophyll in the case of some Algæ; and the starch already formed in the chlorophyll even disappears in a mixed blue light as in the dark. The green colour of Monocotyledons and Dicotyledons may be produced by rays belonging to all parts of the spectrum; but the action of the yellow rays is by far the most powerful; the red and the green have less power, while the blue, violet, and ultra-violet act very slowly. The action of light on the change in the tension of the tissues by which positive heliotropic curvatures are brought about, belongs to the more refrangible (blue and violet) rays; the red and orange appear to be altogether inefficient. The same is the case with paratonic irritation and the periodical movements of the leaves of various plants, as the scarlet-runner and *Oxalis*. On the movement of zoospores the less refrangible (red and orange) rays act like darkness, while the direction of the movement is determined by the blue and by the still more refrangible violet and ultra-violet rays.

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[1] It is an established mode of expression to speak of the blue, violet, and ultra-violet rays as the chemically active, because they are efficient

Light from other sources than the sun, as that of lamps of various kinds or of a body glowing in an electric current (lime-light), appears, from observation, to have the same effect as sunlight, provided that the intensity and refrangibility of the rays are the same. This is especially the case with the electric light.

The chemical processes within the cells of a plant, the molecular movements connected with growth, and the internal changes on which the activity of the protoplasm depends—whether exhibited in the formation of new cells or in motility—are probably connected with disturbances of the *electrical equilibrium*. The fluids of different chemical properties in adjoining cells, the diffusion of salts from cell to cell, their decomposition, the evolution of oxygen from cells containing chlorophyll, the formation of carbon dioxide in growing organs, and the process of transpiration:—all these vital processes must produce electrical currents; although this fact has not yet been experimentally determined or accurately investigated. It has, however, been established that the internal tissue of land-plants is always electro-negative to the strongly cuticularised surface, and that a similar relationship subsists between the surface of roots saturated with sap and the surface of the stem and leaves. Electrical currents which are not too strong only temporarily arrest the motility of protoplasm and the movements of the sensitive parts of plants, while stronger currents destroy the life of the protoplasm, and hence of the plant.

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in the combination of chlorine and hydrogen into hydrochloric acid, the colouring of photographic paper, &c. But with reference to the vital processes of the plant this term is inaccurate, and ought to be abandoned.

Since *gravitation* acts uninterruptedly on every part of the plant, all the parts must be so contrived as to diminish the influence of this force ; and we find, in fact, in the organisation of the plant, a number of contrivances for this purpose. The firmness and elasticity of the wood of erect stems ; the uniform distribution on all sides of the weight of the foliage and of the branches ; climbing and twining internodes which are sensitive to contact, and the various other contrivances that enable slender stems to climb which could not otherwise maintain themselves in an erect position under the weight of their leaves ; the floating apparatus of floating plants, such as the air-bladders in the fronds of *Fucus* and in the leaf-stalk of *Trapa*, and those of *Utricularia* (Fig. 356, p. 184), the floating apparatus, such as the pappus or wings, of many seeds and fruits ; and a number of other specialities of organisation, all serve to counteract the weight of the plant, and to prevent its sinking to the ground where this would be unfavourable to the other functions of the plant. Under the head of the tension of tissues it has already been mentioned that young and weak plants in which there is no tension tend to grow downwards in accordance with the force of gravitation ; while those in which there is tension have a tendency to grow erect ; and this is the reason why roots in general grow downwards and stems upwards. But the influence of gravitation on plants is not yet exhausted, since it opposes a resistance to all internal movements, such as those of water and of the cell-sap whenever their direction is upwards, which resistance the plant must overcome by its internal forces. Light and gravitation are the forces which give to the separate parts of plants, such as the stem and leaves, their normal position, whether erect or horizontal, and therefore, along with the arrangements of the buds and leaves, impart to plants what is termed their Habit.

From the infinite variety of the conditions of life, it is evident that plants must possess a certain power of *adaptation* to their external conditions.

This is seen especially clearly in amphibious plants, which live sometimes in water, sometimes on dry ground ; and in climbing plants. Thus for example, the terrestrial form of *Polygonum amphibium*, with its erect stem and shortly-stalked narrow hispid leaves, is easily transformed, by simply transplanting into water, into the floating form with floating long-stalked glabrous leaves. The branches of the terrestrial form then soon cease to grow, their leaves dry up, and the new plant of the floating form is developed from the rhizome.

ABNORMAL VITAL PHENOMENA AND CONSEQUENT ABNORMAL DEVELOPMENTS.

That section of botany which treats of the abnormal vital phenomena and the consequent abnormal developments of plants, is called *Vegetable Pathology*; and may be divided into two subdivisions, *Teratology* or the study of malformations, and *Nosology* or the diseases of plants. The former is concerned with deviations from ordinary structure in the organs of the plant, the latter with variations in the vital functions. This whole subject, therefore, independently of its practical importance, is also of great scientific interest, the former part especially in relation to morphology, the latter to physiology. It is, however, impossible to draw any sharp line of demarcation between malformation and disease, and often one cannot be conceived without the other.

The causes of the phenomena now under consideration lie in a want of conformity of the plant, partly to the conditions of its environment, partly to those of other plants, and partly also in injuries inflicted by animals. In a certain sense also, treatment by man may be a source of abnormal vital phenomena; inasmuch as he prescribes the conditions in which the plant shall grow. Most cultivated plants live in conditions which were foreign to their uncultivated ancestors, and they have frequently undergone such change that their parentage cannot be recognised. It is, indeed, often the object of cultivation to cause such deviations. Thus, the brussels-sprout is cultivated on account of the monstrous edible thickening of the stem, and the cauliflower on account of its peculiarly metamorphosed inflorescence. A very high cultivation produces, however, other modifications besides those aimed at, and less desirable in themselves. Thus, there is no doubt that the cultivation of fruit-trees has resulted in an enfeeblement of their vegetative organs, and a shortening of the duration of their lives. The same is the case with those plants which man has transplanted from warmer to colder climates or the reverse, or has attempted to acclimatise. In order to understand this, it is only necessary to observe the weakly specimens of tropical plants in our conservatories, and to compare with them drawings made in the primeval forests of their native country. In short, it may be assumed that all cultivated plants are, to a certain extent, disposed to deviate from their ordinary structure; and it cannot. therefore, be wondered at, that they are especially liable to malformations and diseases.

Attention must first be directed to those deviations which are caused by atmospheric influences, or by the nature of the soil. Light, warmth, and moisture, as well as the nature and chemical composition of the soil, are here the active factors; but as to how these act very little is at present known, except what has already been said in the section on the general conditions of plant life (see p. 208). The changes brought about by these influences affect the size and number, the arrangement and shape of the individual organs, in short, the external form of the plant; but they also cause an abnormal activity of cells, from which results a more or less complete disturbance of metastasis and of the processes of life.

The change in size may be partly due to *abortion*, partly to an abnormal increase in size of the organs. The abortion of the primary axis shows itself, as a rule, only in the form of *dwarfing*, that of larger or smaller branches occurs in its purest form in the production of *spines*. Several families of plants, such as the Rosaceæ, are especially distinguished by the frequency of branch-spines whenever the species grow on sterile ground. Like the branches, the leaves can also degenerate into spines. Thus, many species of Berberideæ and Grossularieæ develope spines in the place of particular leaves; and these often, as in the gooseberry, remind one in their form of the three or five-lobed leaf. The abortion of leaves does not, however, always lead to the production of spines. In many species of acacia the lamina is so little developed, that nothing remains but the petiole, which is then called a *phyllode* (Fig. 143, p. 90); and in some species this transformation of the leaf is so common that it can scarcely be considered as abnormal. All these peculiarities, so far as they are not hereditary, *i.e.* transmitted through the seed, are due to the poverty of the soil. As poverty of soil leads to abortion, so an unusual increase in development of the axial or foliar organs is usually the result of too powerful nutrition; either the transmission of nutrient substances from the soil is in itself too abundant, or a want of due proportion between the parts above and below the surface is caused by too vigorous cutting away of branches or leaves. The latter course is generally pursued by gardeners, who aim at obtaining unusually large fruits or flowers by cutting away blossoms, young fruits, leafy shoots, &c. Finally, it has already been stated that an unusual development of the stem may result from a deficiency of light; and this is always the case in the etiolated parts of many plants.

Abnormalities in the number of organs are not uncommon. In the clover, for example, an increase in the number of leaflets of the normally trifoliolate leaf is frequent. In the *dédoublement* or 'doubling' of flowers again, to which more particular reference will be made hereafter, in addition to the transformation of one of the floral organs into another, as stamens into petals, there is generally also a multiplication of the floral whorls; for example, in place of a single whorl of stamens, two whorls of petals, &c., as happens in the pink, which has normally only five petals and ten stamens, but when double, often twenty or more petals. The change in the relative number of parts is not however, always in the way of increase, but as often, perhaps, of a diminution of the number of the organs concerned.

Every part of the plant has, when young, the power of adhering to others in its growth, and does actually do so whenever its formative tissue or cambium comes into contact with that of other parts. This fact, so important for the processes of grafting, budding, &c., is also of some importance in this connection, because very peculiar malformations often result from such *adhesions in growth* between neighbouring plants or parts of plants. It is very common, for instance, to find the pinnæ of *Gleditschia triacanthos* united with one another in such a manner that the bipinnate leaf becomes a simply pinnate or even a simple leaf. Separations of organs which are normally united in their growth also sometimes occur. If, for example, a mallow is made by prolonged cultivation to become double, this change begins by the filaments which were previously united into a single bundle separating from one another, each stamen then becoming transformed into one or more petals.

Of much greater importance than changes in the number, size, and position of the parts of plants, are those which relate to their form. The most common and interesting change of this kind in the stem is the phenomenon known as *fasciation.* This consists either in the stem becoming flattened, and hence assuming a ribbon-like form, or in its beginning to divide irregularly into a number of branches, which at once coalesce laterally with the main branch, [or from the cohesion of a number of buds]. Fasciation occurs especially in ground that has been excessively manured, and hence very commonly in cultivated plants. In them it is often inherited through the seeds, as, for example, in the garden-plant known as 'coxcomb,' *Celosia cristata*, and in the cauliflower, in which the thickened fleshy branches of the inflorescence have coalesced to form a head or mass covered in the upper part with abortive flowers. As in the last case, abortion is almost always associated with fasciation. For while the fasciated part of the stem becomes itself inordinately developed, the buds which are normally produced on it in large numbers either remain altogether dormant, or give rise to weak immature organs or a few fasciated or, less often, separate branches. The terminal bud almost invariably ultimately disappears. Fasciation is frequently associated with curvatures, causing the production of peculiar forms resembling sickles or crosiers, as is not uncommon in the willow and ash.

Far more numerous are the changes in form which affect the leaves. These may be classified into Metamorphosis of Leaves, Peloric Formations, and true Changes of Form.

Goethe was the first to propound the theory, though somewhat poetically, that all the organs of the higher plants can be referred back to a single, or at least, to a very small number of fundamental forms; that, in fact, every organ is either axial (stem), or foliar (leaf), or is compounded of these two. That this is actually the case is shown, not only by the history of development, but also by a close investigation of those abnormal processes which are called *metamorphosis.* According to Goethe a foliar organ must be considered the more highly developed the higher it stands on the axis of the plant, the nearer therefore it is to the centre of the flower; and an ascending series can be constructed as follows: —Leaf-spine [Scale-leaf], Foliage-leaf, Bract, Sepal, Petal, Stamen, Carpel. The metamorphosis may be either progressive or retrogressive, according as the transformation of the foliar organs takes place in the direction of a higher or lower member of the series. Instances of *retrogressive metamorphosis* are furnished by the production of leaf-spines and leaf-tendrils already mentioned, which may be considered as consisting essentially in an abortion of the lamina and a reduction of the leaf to the lignified petiole or mid-rib. Equally common is the retrogression of bracts to the form of foliage-leaves; as in the spathe of Aroideæ, which often has a leaf-like form. The retrogression of sepals into bracts or foliage-leaves is still more frequent, a common and beautiful example of which occurs in the calyx of the rose. One of the best known instances of metamorphosis of the reproductive organs into perianth-leaves is furnished in the case of the common garden tulip, in which the three carpels and the six stamens are all transformed into ordinary petals ; [and the same is the case with the greater number of double flowers, as the rose, camellia, pink, &c.]. That these leaves are actually lower stages of development of the organs, is shown very clearly in an imperfectly double tulip, in which some of the leaves are divided through their mid-rib into two altogether unlike halves, a half-stamen and a half-petal. These imperfect transformations are also frequently seen in the peony and the water-lilies (Nymphæaceæ)—[in the case of the white water-lily, *Nymphæa alba*, even in the wild state]—these instances affording convincing proof that the 'doubling' of flowers is due to retrogressive metamorphosis. It has already been mentioned that this metamorphosis is very commonly accompanied by an increase in the number of parts of the flower ; and it is not surprising that such retrogressions should also be associated with abortion. Perfectly double flowers are of course sterile ; but even when the metamorphosis affects the stamens only, the pistil is in that case also always less perfectly developed, and less or even not at all capable of being fertilised by pollen from other flowers. In many cases the doubling is only apparent, as in the cultivated Compositæ, such as the aster and dahlia, in which the altered appearance is produced by the transformation of the yellow tubular flowers of the disc into ligulate flowers of a different colour ; but sometimes only by the increase in size and change in colour of the tubular flowers. In this case also the transformation is usually associated with sterility. When the retrogressive metamorphosis goes back still further than in the doubling of flowers, the brightly coloured petals lose their colour, and the flower becomes green.

Such instances of *chloranthy* are common in the Leguminosæ, and especially in clover.

Instances of *progressive metamorphosis* are much less common, though a number are to be met with. The most common example is the metamorphosis of petals into stamens. It is not uncommon to find the shepherd's purse, *Capsella bursa-pastoris*, with ten stamens and no petals, the normal number being four petals and six stamens. A metamorphosis of stamens into carpels is also not unusual in willows, making them apparently monœcious, whereas they are normally diœcious.

Changes of form arising from the metamorphosis of whole parts of plants may be divided into four groups:—the solution of flowers or Antholysis, Prolification, Gemmation, and the Metamorphosis of Buds. By *antholysis* is meant those separations of the parts of the flower by which their relative number and position are so altered that the normal construction is completely concealed. *Prolification* is the elongation of the apex of the floral axis above the flower, where it bears fresh buds, leaves, and flowers, as occurs normally in the syncarp of the pine-apple, and not unfrequently in roses [and pears]. *Gemmation* is the production of buds in the axils of the floral leaves, which then develope into new flowers or inflorescences, as is not unfrequently the case in the capitula of *Scabiosa* and *Dipsacus.* Finally, it is not uncommon for leaf- or flower-buds to be transformed into fleshy bodies with small scale-like leaves and a very short fleshy axis. These buds, which often serve as a reservoir for the reception of assimilated reserve-materials, very commonly grow, when detached from their parent-plants, into independent plants. Species in which this phenomenon commonly occurs [as *Polygonum viviparum*, *Poa vivipara*, &c.], are called *viviparous.* In the above and some other species it occurs normally, and is not uncommon in many natural orders, as Liliaceæ, Gramineæ, Cyperaceæ, and Juncaceæ. The buds in the axils of the leaves of *Lilium bulbiferum* (Fig. 350, p. 179) and in the inflorescence of many species of *Allium* come under this head.

Closely connected with metamorphosis is *peloria*, or the abnormal regularity of flowers usually irregular but symmetrical, *i.e.* so constructed that there is only one line by which they can be divided into two similar parts. This phenomenon is most common in Gramineæ, Leguminosæ, Labiatæ, Scrophulariaceæ, and Violaceæ. In the common toadflax, *Linaria vulgaris*, for example, in which the personate bi-labiate corolla runs out into a spur, the terminal flower of the raceme not unfrequently exhibits complete peloria, *i.e.* has a regular margin, and five spurs at equal distances from one another. In Compositæ, peloria frequently takes the form of a conversion of the ligulate into tubular flowers.

The last class to be mentioned is the change in the external form of leaves, the result of an irregular accession or suppression of growth from disease. Deviations from a symmetry between the right and left side of the leaf occur normally in some plants, as the various species of Begonia [and lime], and occasionally in almost all plants. The relationship between the length and breadth of the leaf is also often disturbed. A difference frequently occurs between the intensity of growth of the vascular bundles and of the parenchymatous tissue (mesophyll) which occupies the space between them. When the vascular bundles grow more vigorously than the parenchyma, the latter is ruptured, and the leaves become perforated or slit, as is always the case in old leaves of the banana [and in some Aroideæ, Fig. 194, p. 106]. When, on the other hand, the growth of the parenchyma exceeds that of the vascular bundles, the leaves become crumpled, as in many garden-plants such as endive, parsley, &c. More rarely, outgrowths are developed on the surface of the leaf, which themselves assume a leaf-like form.

In all the cases hitherto mentioned we have treated only of changes in form. But diseases are also caused through the influence of the soil, depending on an abnormal transformation of those substances out of which the tissue of the plant is constructed. These constitute what are called *secretional diseases*, in which cellulose is transformed into gum, resin, or manna. These diseases are, properly speaking, only excessively vigorous phenomena of vital functions which in many plants are quite normal. It is remarkable that effusions of sap of this nature are often the result only of external injury, and are commonly increased by removing the substance excreted, as in the production of resin.

The consideration of secretional diseases leads to that of *diseases of decomposition*. These diseases, which are frequently confounded or blended with the former—known generically as *gangrene* or *canker*—are processes of decay in which the cellulose is transformed into a muddy fluid, a brown humus-like powder, or a carbonaceous mass, such as never occurs in a normal state. Decompositions of this nature are promoted, or, perhaps, are first caused, by swarms of low microscopic organisms, Fungi and Algæ, which find in the dissolution of the organic substance a favourable substratum for their development. It is impossible to enter in this place on a more minute discussion of the processes of fermentation, decay, and putrefaction, and of the points which are still in dispute as to the part played by the organisms which always accompany these processes, and as to their systematic position. It is, however, certain that diseases of this kind are characterised by the presence of organisms, and are by this distinguished from secretional diseases. In reference to the external form in which they present themselves, a distinction is to be drawn between moist and dry gangrene, according as the product of decomposition of the cellulose is a fluid or a solid substance. The latter form very commonly first attacks the innermost layers of wood, which may be, according to the colour of the substance formed, red or white. Plants attacked by decay may still live a long time under certain circumstances, and may have a perfectly sound appearance on the outside, until the disease reaches the cambium-layer, when they quickly perish. The decomposition of cellulose does not, however, always begin inside the plant; it may also penetrate from without, at spots which have become diseased from external injury.

Diseases of another class, produced by vegetable *parasites*, that is by plants which derive their nourishment from the living tissue of the plants they inhabit, are in general less obscure than those which were last described.

Among these parasites are certain Fungi (Fig. 374), which are of the greatest practical importance. The question which has often and for a long time been discussed respecting these plants, whether they are the cause or only the accompaniment of the disease, has now been decided in favour of the former alternative, since it has been proved that the organisms in question are well-defined species of Fungus, and that the same organism is always found to accompany the same disease. In addition to this, it has been

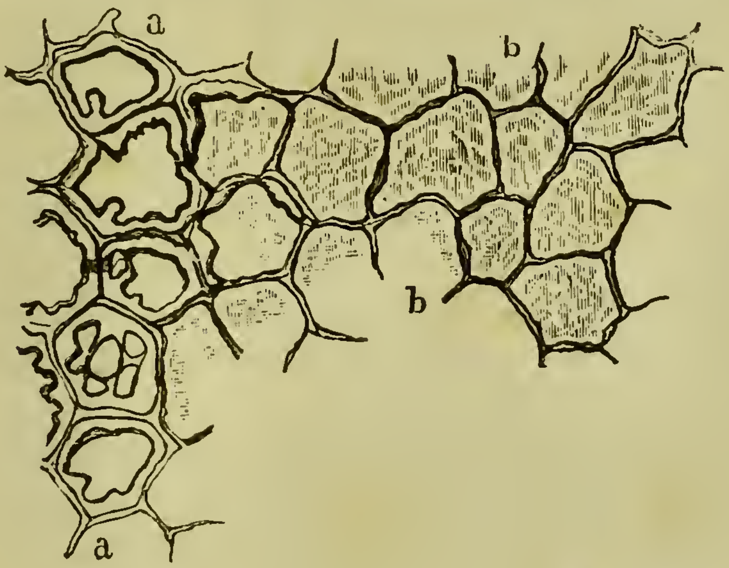

FIG. 374.—Destruction of the cell-wall caused by a Fungus: transverse section of the wood of a beech; at *a*, *a* the destruction of the secondary layers is still in progress: at *b*, *b* the entire cell-wall has been destroyed with the exception of a larger or smaller residue of the primary layer, and the cell-cavity filled with an amorphous substance.

proved by a number of observations and careful experiments, that these diseases are contagious, and that healthy plants become subject to a particular disease when the spores of that Fungus are sown upon them which always occurs in connection with that disease; and that, finally, the best means for preserving or restoring the health of the plant are those by which the spores of the Fungus are destroyed. This does not, however, prevent other Fungi occurring as accompaniments of the particular disease besides the one to whose attacks it is due.

Among the most important of the diseases of this nature to which cultivated crops are liable is the *rust* or *mildew* of cereals. This term is appropriately given to a disease in which, at least at first, reddish masses of a brown rust-like dust break out from the internal tissue of the plant. It is most common on barley, wheat, and oats, less so on rye and wild grasses. Since it chiefly attacks the vegetative parts, the leaves and succulent stems, and but rarely the seeds, the injury caused by it consists mainly in a deterioration of the straw; but the grains are also of inferior quality, when the parts which contain chlorophyll, and which consequently assimilate, are attacked at an early stage. The species of mildew which infest cereal crops are mainly two, *Puccinia graminis* (Fig. 400, p. 277) and *P. coronata*. The very remarkable course of development of the latter will be afterwards more exactly described when speaking of Fungi.

Smut shows itself first on the organs of fructification, the epidermis of which is irregularly ruptured in a great number of places, a black dust then appearing through the slits. It attacks the different parts of the flower in a very unequal degree. The whole of the parenchymatous tissue is often destroyed; and this occurs to so great an extent in winter-barley, that of the whole ear the common rachis of the inflorescence alone remains, while frequently, as in oats, the seed only is destroyed, the paleæ remaining unaffected. Especially in the last stage of the disease, the masses of dust also emerge from the culms beneath the flowers, as well as from the leaves. Rye and wheat are also subject to this disease, wild grasses less so. It is caused by the attacks of a Fungus, *Ustilago carbo*, the black masses consisting of its emerging spores which project between the paleæ, the mycelial threads obtaining their nutriment from the interior of the parenchymatous cells.

The smut of maize and millet are of a similar character. In the former swellings the size of the fist or even of the head are formed in the diseased part, between the cells of which the filaments of the Fungus which produces the disease, *Ustilago maydis*, are easily found. The millet-smut, caused by *Ustilago destruens*, destroys the whole of the flower even within the leaf-sheaths.

Bunt is a disease which attacks all kinds of wheat, but the varieties of spelt have less to fear from it than other sorts, and winter- less than summer-wheat. The Fungus which produces this disease, *Tilletia caries*, fills up with its spores the whole of the ovary, and replaces it by an elongated, black, greasy body of a disagreeable odour. The mycelium is easily found in the parenchyma of the flower.

Ergot is another Fungus of this kind, which attacks the inflorescence of grasses, and especially of cereal crops, appearing in the place of the fruit in the form of an enormously large grain among those that are still healthy. In form it resembles, therefore, the grain which it attacks; in rye, for example, it is obtusely triangular, and in *Phragmites* flatly compressed. It is the 'sclerotium' of a Fungus which grows from the base of the ovary, and soon detaches it from its point of attachment, raises it up and then encloses it or presses it aside. Ergot, although it seldom occurs in any great quantity, is one of the most dangerous vegetable parasites of cereal crops, since it contains a powerful poison, on account of which it is valuable in medicine, but which renders the meal quite useless when ground with it. The various stages of development of the ergot of rye received a number of different names before their connection with one another had been ascertained. Thus the delicate mycelium from which ergot originally springs has been called *Sphacelia segetum*, the ergot itself *Sclerotium clavus*, *Secale cornutum* [or 'spurred rye'], and the fructification which developes from it (Fig. 375) *Claviceps purpurea*; the last being the name now given to the Fungus.

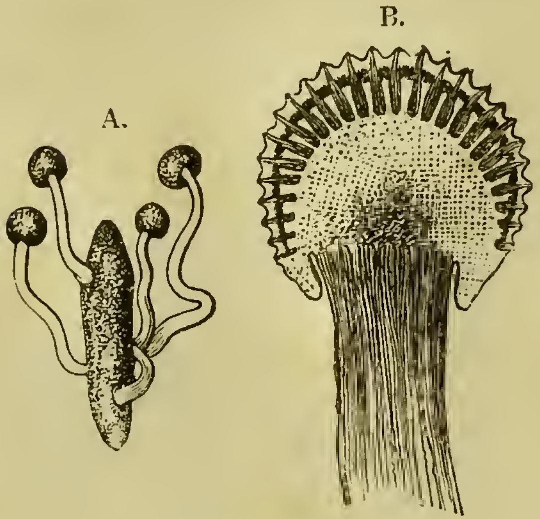

Fig. 375. — Ergot; A, with four fructifications (natural size); B, longitudinal section through a fructification with its perithecia. (Magnified.)

Mention must also be made of a number of diseases about which but little is yet known, and which have this in common, that they appear as black velvety coatings on the leaves, and especially on their upper side. There seems to be frequently, but not invariably, a connection of alternation between the 'honey-dew'[1] caused by aphides and these diseases, the aphides encouraging the settlement of the Fungi, *Saccharomyces* and *Cladosporium*, which give rise to the latter.

A similar appearance is presented by vines attacked by the *vine-mildew*, *Erysiphe Tuckeri*. The course of this disease is, in its essential points, as follows:—A delicate white shining growth is seen, as a rule after the blooming time, and at first on the under side of the leaves, then on all the young parts of the vine (Fig. 376), which finally invests these parts more and more completely, without, however, penetrating into the interior, as it only puts out short organs of attachment here and there. These drain the epidermis ; the grapes remain small, and finally burst, the fleshy interior being forced out of one or two intersecting clefts.

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[1] Honey-dew is a sweet juice exuded by various species of Aphis; [or believed by some to be an exudation from the leaf itself].

The English gardener Tucker was the first to remark, in the year 1845, the Fungus which was named after him, but without recognising its nature. The disease appeared at Versailles in 1850 ; and in 1851 under various conditions, and in widely scattered districts, in France, Italy, and Germany. In Madeira, the vine, which had been cultivated since the fifteenth century, was attacked in 1852 ; in several succeeding years the crop completely failed; and this induced the inhabitants to abandon the cultivation of the grape for that of the more profitable sugar-cane ; so that for twenty years after 1851 scarcely any Madeira wine was produced. From that time the disease, favoured by damp warm weather, has spread locally to the whole of Europe, no remedy having been up to the present time discovered for it.

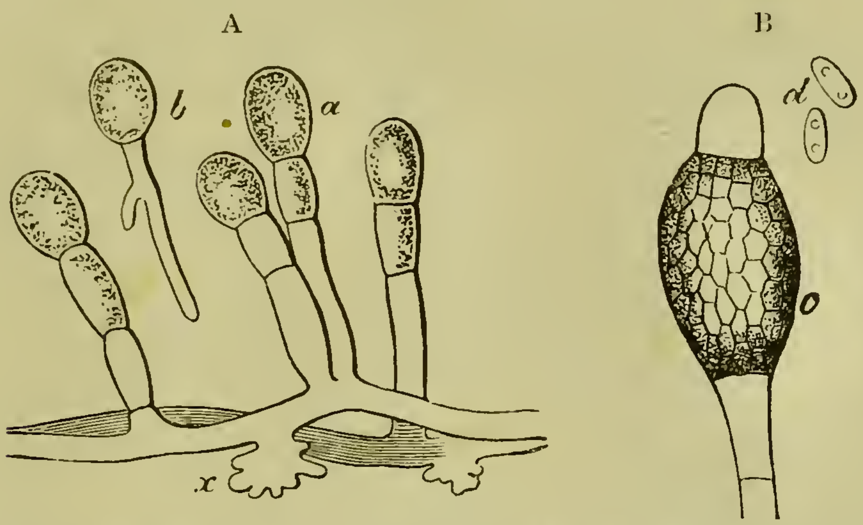

Fig. 376.—The vine-mildew ; A, the fungus *Erysiphe Tuckeri* : *a* the conidiospores becoming detached ; *x* the organs of attachment, or haustoria ; *b* a germinating spore (× 400). B, *c* a fungus (*Cicinnobulus Cesatii*) parasitic on the *Erysiphe*, and formerly regarded as a special mode of reproduction of it ; *d* its spores (× 450.)

Next to the vine-disease the *plum-disease* is one of the most destructive parasitic diseases of the different kinds of stone-fruit. The malformations produced by it, and known under the name of 'pods' and 'pockets,' are distinguished from the dark juicy fruit covered with a bluish bloom by their greater length and flatness, by the want of the hard stone, and by their invariably lighter colour. The prematurely ripe fruits fall off and are worthless. The cause of the disease is a Fungus, *Exoascus Pruni.*

The *Potato-disease* makes its appearance first on the green parts of the plant, forming brown spots on the leaves and stems, usually in July and August. A short time afterwards the tubers are found to be diseased, and begin to decay. The decomposition is either moist and of a disagreeable odour, or ends in a drying up of the tissue; the former kind being generally described as the true potato-disease, although the two forms pass into one another. It is only rarely that the decay of the tubers precedes the sickening of the plant itself. The parasite which causes this disease is also a Fungus, *Phytophthora infestans* (Fig. 397, p. 273). It penetrates the tissue of the leaf, its conidia bearing filaments projecting through the stomata. The tissue of the leaf dies under its influence, and the tubers which are subsequently attacked also decay (Fig. 377).

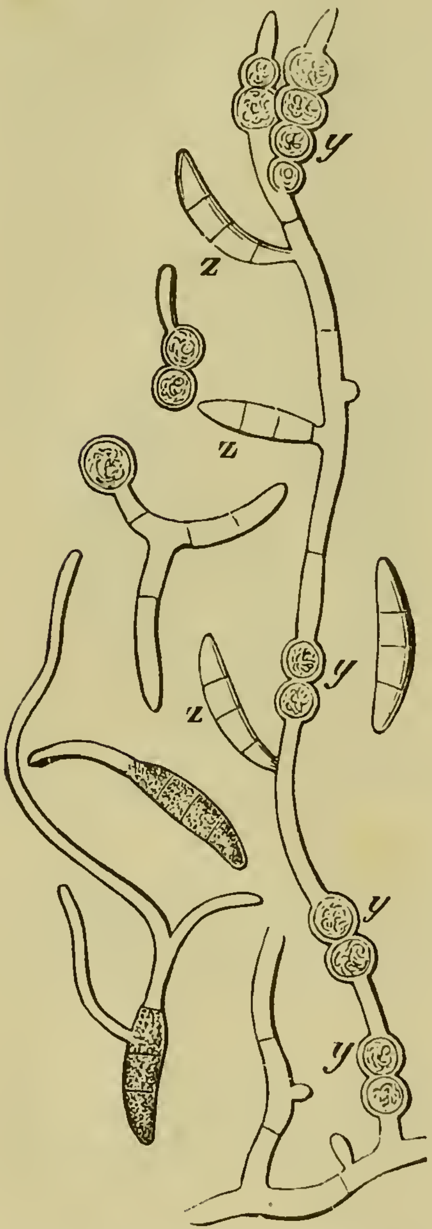

Fig. 377.—Fungus-filaments from a rotten potato, together with the spherical spores *y* called *Oïdium violaceum*, and the longish multicellular spores *z* of *Fusisporium Solani*; young plants are germinating from both forms. (This fungus very commonly accompanies, but is not the cause of, the disease. × 400.)

The true potato-disease broke out about the year 1830, and spread with terrible rapidity during the next ten years; and has never since entirely disappeared. Its study suggested a variety of causes: among the rest damp weather, too strong manuring, and the cutting up of the 'seed-potatoes.'

A peculiar disease, also caused by a Fungus, but which has not yet been sufficiently investigated, is one of considerable practical importance, the *beet-disease.* It shows itself sometimes in the winter, its presence being manifested by the root becoming light-brown and transparent from without inwards.

The diseases to which bulbs are subject have been but little studied. In the ring-disease, called also the *hyacinth-pest*, rust-coloured spots spread from the disc over the scales, advancing from below upwards. The innermost scales are first attacked, the leaves turn yellow, the flower-stalk decays, and finally the whole bulb degenerates into a muddy mass. The so-called *white smut* consists in the bulbs rotting from above downwards under the influence of a white slime.

Besides the diseases already named, there are many others of less practical importance caused by parasites. Of these causes of disease, phanerogamic parasites are in general less injurious than cryptogamic. Of the former there are only a very few natives of Europe, the mistletoe (*Viscum album*), *Loranthus europæus*, *Lathræa squamaria*, the dodders (species of *Cuscuta*), the various species of *Orobanche*, *Monotropa Hypopitys*, and *Thesium humifusum.*

The mistletoe usually grows on the apple, but also on other trees. It weakens the trees which it attacks by the penetration of its sucking-roots (Fig. 378 I.), and causes the formation of knots, sometimes killing the branch on which it grows, or even the whole tree.

The various species of *Cuscuta* (dodder) germinate in the ground, and only subsequently strike their roots into the neighbouring 'host :' but they also develope above ground their 'haustoria' or sucking-roots at those spots where they come into contact with the plants which they embrace. *C. europæa* grows readily on hedges and thickets, and attacks the hop, [stinging-nettle], hemp, and other herbaceous [and shrubby] plants. *C. epilinum* is exceedingly destructive to flax. *C. Trifolii* (Fig. 378 II.) is especially injurious to fields of clover and lucerne, spreading itself centrifugally from single points, and entirely destroying the vegetation. *C. epithymum* is indigenous, chiefly on gorse and heather.

Of the species of *Orobanche* or broom-rape, which mostly grow on the roots of wild plants, the only ones of practical importance are *O. minor* and *ramosa.* The former occurs especially on clover, while the latter mostly attacks hemp, but also tobacco and nightshade (*Solanum*); (see Fig. 346, p. 166).

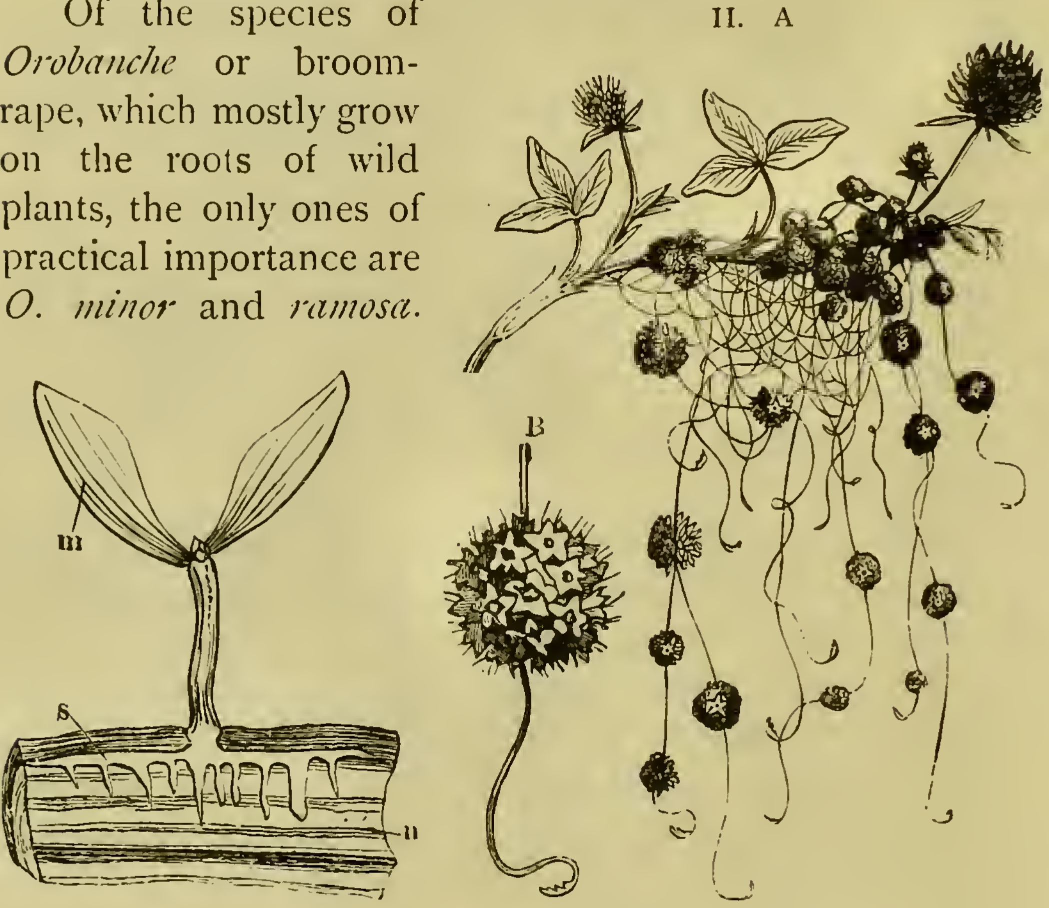

FIG. 378.—I. *n* a piece of a branch of an apple-tree cut through lengthwise, into which a young mistletoe-plant *m* has driven its sucking-roots *s* (reduced): II. *Cuscuta Trifolii*: A, parasitic upon clover (reduced); B, a separate inflorescence (natural size).

The remaining phanerogamic parasites named above have but little scientific interest; to them may be added the various species of *Melampyrum*, *Rhinanthus*, and *Pedicularis.* No further notice is required of the phanerogamic parasites of tropical and subtropical primeval forests, &c., belonging to the natural orders Balanophoraceæ, Rafflesiaceæ, Loranthaceæ, &c.

Besides these parasites, there are various flowering plants which are injurious as weeds, depriving other plants of light and nourishment and therefore of the most essential conditions of life, or themselves stunting them in their growth by climbing over or twining round them, and dragging them to the ground.

Reference must finally be made to *epiphytes*, or those plants which only grow on other plants without deriving nutriment from their tissues. Plants of this class which occur in our zone, for example, many Mosses and Lichens [and some Ferns], can scarcely be considered as pathogenous.

The injuries which plants receive from animals are extremely numerous and various. When the injury is to the root, it results in an insufficient supply of nutriment to the plant; when, on the other hand, it is the leaves that suffer, the absorbed food-materials are not assimilated in sufficient quantity, and the plant suffers from weakness or exhaustion. Injuries to the bark cause 'bleeding,' gangrene, or decay. There are also a number of animals that live in or on plants, which, without visibly injuring them externally, cause an irritation in the parts of the tissue affected which results in morbid phenomena. It is common, for example, to see the leaves of the hop, cabbage, and other plants, crumpled up into blisters and rendered unhealthy by the attacks of some species of aphis on the under side. The form of these abnormal productions is usually so characteristic that it is possible from them to determine the animal by which they are caused, and *vice versâ*. Thus, *aphides*, which lay their eggs in the plant, cause blister-like swellings, in which the larvæ live until the period of their metamorphosis, at the expense of the plant. The structures which they produce, and which are generally not injurious, are sufficiently well known in the lime, hazel, elm, and other trees and shrubs. *Willow-galls* and *rose-galls* are a somewhat higher form of these bodies. The former are produced especially on willows by the puncture of the *Cecidomyia* *strobilina* in the leaf-buds, which causes arrest of growth, the stem scarcely developing, and the leaves becoming crowded together into a close rosette. The rose-gall is caused by *Rhodites Rosæ* laying its eggs in the branch, the stem then swelling up to a considerable size from the exu-

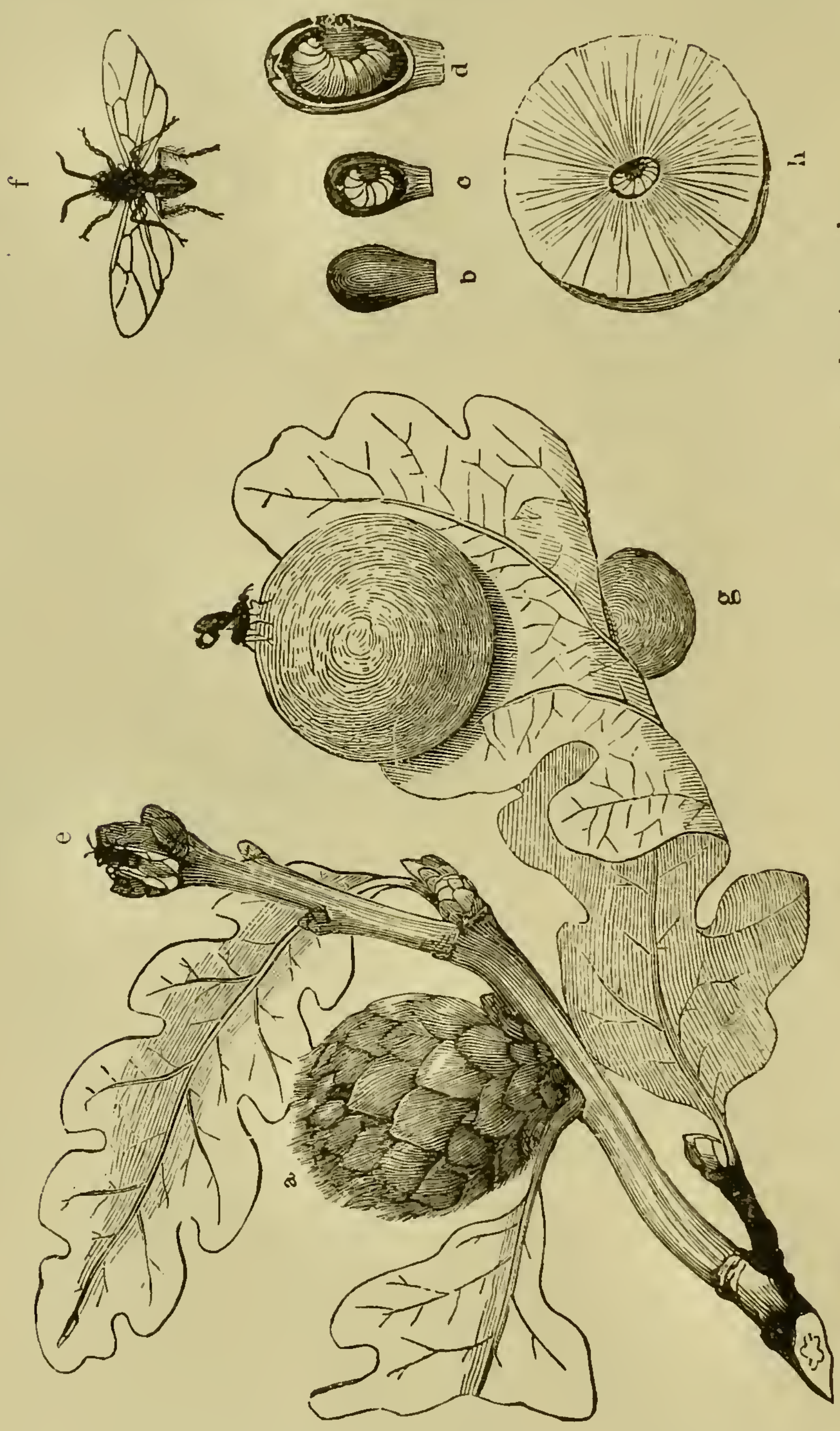

Fig. 379.—Galls and gall-wasps: *a–d* the oak-apple-wasp, *Cynips fœcundatrix*; *a* oak-apple; *b* cocoon; *c* cocoon cut open (natural size); *d* the same (magnified); *e–h* the common oak-gall wasp, *Cynips scutellaris*; *e* the insect (natural size); *f* the same (magnified); *g* oak-gall; *h* the same cut open, showing a larva in the chamber in the centre (natural size).

berant growth of the parenchyma, while the leaves are produced in ordinary numbers, but with scarcely any parenchyma between their fibro-vascular bundles, causing the misshapen branch to appear as if covered with moss. The highest form of development of these structures is seen in the true *galls*, the production of which is due to punctures made in the leaves, flowers, fruits, buds, and young bark by the female gall-wasp, belonging to various species of *Cynips*, which then lays its eggs in the wound. The various kinds of gall are most abundant on the oak-tree, on which the total number of species that have been observed is upwards of 150. The best known is the common *oak-gall*, produced by the puncture of *Cynips scutellaris* on the under side of the leaf (Fig. 379).[1] As morbid phenomena galls are usually of but small significance. Whether they are regarded as the nidus of a number of useful insects, or, many of them, as articles of considerable value in commerce, their usefulness greatly exceeds the injury which they inflict on the plant.

It would occupy too much space to enumerate those animals which are hurtful to the plant by the external injuries inflicted by feeding on them, &c. The part which insects play in this respect is well known to every observer of nature.

AGE AND DEATH OF PLANTS.

If the life of a plant is not shortened by any disease, and if no animal or man appropriates it to its own purpose, gathers it, and kills it, its term of life is still usually limited. Some die after they have once produced fruit [*monocarpic* plants], one or two years [*annual* or *biennial* plants] being required for their development; while others [*polycarpic* plants] produce fruit many times and live for many years, attaining sometimes an enormous age. The silver-fir seldom flowers under thirty or forty years ; the Scotch fir and larch, on the other hand, produce cones in ten or twelve years ; the oak and beech, again, only flowering when they have attained a considerable age. The Scotch and spruce-fir attain their full height, as a rule, in from 80 to 100 years, while the silver-fir requires a longer period. The annual rings of the beech usually become less distinct after 130 or 150 years, while the regular increase of the oak in girth does not diminish till it is 150 or even 200 years old ; and in the sweet chestnut the increase continues for at least double that period in the south of Europe. Probably the oldest lime-tree in Germany, at Neustadt on the Kocher, was celebrated in song as long ago as the year 1408 ; and the silver-firs on the Wurzelberg in the forest of Thuringia must be, from the number of the annual rings in one of the oldest trunks, 600 years old. The age of an oak at Breslau, more than 13 metres in girth at a height of 26 metres, is estimated at 700 years. The old rose-stock in the crypt of the cathedral at Hildesheim was planted, according to tradition, by Louis the Pious ; and the old dragon's-blood tree at Orotava in Teneriffe, is said to have been as vigorous—and even to have been hollow—in 1402, when the island was taken by the Spaniards, as in 1868, when it was blown down in a storm. All previous conceptions of the size and age of trees are enormously exceeded by the facts ascertained respecting the *Sequoia* (*Wellingtonia*) *gigantea*, the 'mammoth-tree' of California, the largest measured specimen of which gives a diameter of 10 and a height of 120 metres, and, judging from the number of its annual rings, an age of from 3,000 to 4,000 years. The bread-fruit-tree is said to attain an age of from 5,000 to 6,000 years ; that of the gigantic species of *Eucalyptus* of Australia, from 130 to 160 (?) metres in height, has not been ascertained.

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[1] [*Oak-spangles* are smaller, flat bodies, produced also on the under side of oak-leaves by the attacks of an insect, *Diplolepis lenticularis*. —Ed.]

CHAPTER VI.

SPECIAL MORPHOLOGY AND CLASSIFICATION.

Even the most superficial observation of the vegetable world is sufficient to show that no form exists on the earth as a single individual, but that each is repeated with very slight variations. These variations, however, refer only to the size, colour, degree of hairiness, and other external character of the separate organs, to the number of branches, leaves, and flowers, in short to points so unessential that the same name is naturally given to all these similar individuals. Closely connected with this is the additional fact that new individuals which spring from seeds resemble exactly the individuals which produced the seeds, with the exception again of slight and unimportant variations. The entire collection of those plants which thus coincide in all essential characteristics, and of all those which are descended from the same parent, is called a *Species*. But a species remains unchanged, even within the limits defined by essential characteristics, only as long as the vital conditions remain the same. When these are altered by change of climate or food, or of relationship towards other organisms, whether man, animals, or other plants, even some of these characters gradually disappear, and are replaced by others. A species is therefore only an assemblage of forms which resemble one another for the time being, and is not a type rigidly defined by nature.

Dependent on changes produced by cultivation, a species is divided into *Sub-species* ; and when the characters are hereditarily transmitted with constancy through the seed, into *Races*. Variations within the same race are called *Varieties*, and these again are divided into *Sub-varieties*.

All species which agree in the essential characters of their organs of reproduction—the parts of the flower, seeds, spores, &c.—form together a *Genus*. The different species belonging to the same genus may differ very considerably in their vegetative organs ; but the slighter these differences the more natural is the genus.

Since the time of Linnæus two names have been given to every plant, a generic and a specific name, the generic name being placed first, and the specific name last. Thus the cucumber is *Cucumis sativus*, the melon *Cucumis melo*, both belonging to the genus *Cucumis*.

Since the conception of a genus is defined arbitrarily, according to the individual view of each naturalist, and that of a species is no more natural, it has come to pass in the course of time that one and the same plant has received several specific and generic names, or that the same name has been given to different plants. In order to distinguish clearly the particular plant meant, it is usual to append to its name that of the botanist who first bestowed it. Thus by the phrase *Conium maculatum* Linn., is meant that Linnæus was the first to give this name to the common hemlock. In the present work the name of the authority will not be given, because only those plants will be mentioned with respect to which there will be little danger of a mistake as to the species intended.

For the purpose of obtaining a general view of the enormous number of plants, and their mutual similarities or relationships, their classification into genera is not sufficient. Those genera which are nearly related, *i.e.* which resemble one another in the form and mode of arrangement of their organs of reproduction, are collected into *Families*; these into *Orders* ; and these again into *Classes*. Several classes go to make up a *Sub-kingdom*, and the whole collection of sub-kingdoms constitutes the Vegetable Kingdom. Since, where the relationships are complicated, it is often necessary to distinguish steps even intermediate between these, it is usual to arrange the orders which make up a class into *Series*, the genera which make up a family into *Tribes*, and the species which make up a genus into *Sections*. To denote still further sub-divisions, the prefix 'sub' may be placed before any of the terms mentioned, so as to mark still further intermediate grades ; thus a *Sub-family* is a grade between family and tribe, a *Sub-tribe* a grade between tribe and genus, &c.

The system of classification [1] at present in use has gradually grown up from a combination of those proposed by Jussieu, De Candolle, Endlicher, Lindley, Bentham, and other systematists. The vegetable kingdom is first divided into two great sections, Cryptogamia and Phanerogamia, the former being destitute of flowers containing anthers and ovules, the latter having these organs.

Cryptogamia are again divided into four groups or subdivisions, viz.:—

1. THALLOPHYTES or Leafless Cellular Cryptogams. Plants which have no leaves and no vascular tissue, but are constructed of cells only. There are, however, certain transitional forms which must not be overlooked between these and the leafy Cryptogams. To this sub-division belong : 1, *Protophyta* ; 2, *Algæ* ; 3, *Fungi.* It is impossible to lay down accurate lines of demarcation between these three classes ; but it may be stated broadly that Algæ contain chlorophyll, and are therefore able to avail themselves of inorganic food-materials ; while Fungi contain no chlorophyll, and are therefore not able to make use of absorbed unassimilated food-materials, but are compelled to live as parasites on other organisms, or on organic remains. The lowest forms of vegetable life, unicellular organisms, with no known mode of sexual reproduction, whether containing chlorophyll or not, make up the Protophyta.

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[1] [In order to adapt this section to the requirements of candidates for the London University Examinations, very considerable alterations have been introduced in the mode of classification adopted in the original, and the descriptions of particular forms have been amplified. No full unanimity has yet been arrived at with respect to the best system of classification of Cryptogams, especially of the lower Thallophytes, the life-history of some of which is still but imperfectly known. I have here followed, both in classification and in terminology, the last edition of Henfrey's 'Elementary Course of Botany,' the descriptions of the groups being largely borrowed from that work.—ED.]

2. CHARALES. Submerged water-plants readily recognised externally by their organs of reproduction, and by their verticillately branched vegetative organs. Their distinguishing characteristic lies in the peculiar phenomena connected with their mode of sexual reproduction (Figs. 418-420, pp. 292, 293). They consist of a single class only, the *Characeæ.*

3. MUSCINEÆ. We have here a distinctly marked alternation of generations. From the spore is developed either directly (in most Hepaticæ) or indirectly, as the lateral branch of a so-called *prothallium* (in some Hepaticæ and all Musci), a plant which bears the organs of reproduction; this is the first [sexual] generation. The result of fertilisation is the second [non-sexual] generation, a fruit-like structure, the *sporogonium*, in which the spores are formed. This group is divided into two classes: 1, *Hepaticæ*, and 2, *Musci*, of which the former has capsular sporogonia, usually opening with valves, and containing, in addition to the spores, *elaters*, i.e. elongated spirally thickened cells (Fig. 422, III. p. 297) [the object of which is to assist the dissemination of the spores]; while the sporogonia of Musci have usually a removable lid or *operculum* and do not contain elaters. In the Musci and the higher Hepaticæ we have, for the first time, a differentiation of the vegetative structure into distinct stem and leaves.

4. VASCULAR CRYPTOGAMS. These possess true vessels, and are also characterised by the development from the spore of a leafless prothallium of small size, bearing the oospheres from which, after fertilisation, the spore-bearing plant is produced. The former is, therefore, the sexual, the latter the nonsexual generation. They are classified into two series—the *Isosporous* and the *Heterosporous*. The former produce only one kind of spore; the prothallium, which is developed from this, grows for a considerable time independently of the spore, and bears both the male and female organs of reproduction [*antheridia* and *archegonia*]. The

Heterosporous Vascular Cryptogams produce, on the contrary, two kinds of spores, larger or *megaspores* (often called 'macrospores'), and smaller or *microspores*. From the former arise prothallia, on which the oospheres are developed; while the latter produce only a slight trace of prothallium, and almost immediately the male elements, the spermatozoids or antherozoids. The Isosporous Vascular Cryptogams are divided into three classes: 1. *Filicales*. The prothallium is usually above-ground and green; the sporangia are epidermal structures (trichomes) of the leaves. 2. *Equisetales*. The prothallium is above-ground and green; the verticillate leaves are provided with sheaths; the sporangia are formed several together on the margin of peltate scales, which form a terminal fructification. 3. *Lycopodiales*. The prothallium is above-ground and green; the leaves are small and very closely imbricate; the sporangia being formed in their axils. The Heterosporous Vascular Cryptogams include the two remaining classes:—4. *Rhizocarpeæ*. The sporangia are formed in considerable numbers in the interior of hollow capsules, the sporocarps, and contain either a single megaspore or a number of microspores. 5. *Selaginellales*. The sporangia are produced singly on the upper side and near the base of the leaf. The megasporangia contain a small number of megaspores, the microsporangia a large number of microspores.

Phanerogamia or Flowering Plants are classified into two divisions:—1. GYMNOSPERMIA, in which the ovules are naked, *i.e.* not enclosed in an ovary; and 2. ANGIOSPERMIA, in which they are so enclosed. The alternation of generations is in them concealed in the formation of the seed. The pollen-grain corresponds to the microspore, and the embryo-sac to the megaspore of the Heterosporous Vascular Cryptogams. Gymnosperms comprise the *Cycadeæ*, which have a simple stem and pinnate leaves; the *Coniferæ*, with branched stem and simple usually acicular leaves; and the *Gnetaceæ*. Angiosperms are divided into two classes, *Monocotyledones* and *Dicotyledones.* In the former the embryo has only a single cotyledon, the vascular bundles of the stem are dispersed, the leaves are usually parallel-veined, and the prevalent number in the parts of the flower is 3. In Dicotyledons the embryo has almost always two opposite cotyledons, the vascular bundles are united in the stem into a more or less complete ring, surrounding a central (axial) pith, the leaves are net-veined, and the prevalent number in the parts of the flower is 5 [or 4].

CRYPTOGAMIA, OR FLOWERLESS PLANTS.

THALLOPHYTES.

Class I. *Protophyta.*

Under this class are comprised the simplest forms of vegetable life, whether containing chlorophyll or not, in which all the functions of life, both nutritive and vegetative, are performed by a single cell. It follows that there can be no mode of sexual reproduction, consisting in the coalescence of the contents of a male and female cell. The cells are always microscopic, and a number are frequently enclosed together in a common gelatinous envelope (Fig. 59, p. 37). When free, they are often endowed with spontaneous motions of various kinds. The Protophyta are divided into two sub-classes, according as they contain chlorophyll or not.

Sub-class I. Protophyceæ or Phycochromaceæ.

The cells contain chlorophyll, either pure, or coloured by a bluish pigment (*phycocyanin*). They are either isolated, and then frequently provided with vibratile cilia, or united together in colonies by a gelatinous envelope; or they are elongated filaments, sometimes divided by extremely delicate transverse septa, and endowed with a slow undulating motion. The following families are moderately well defined:—

Chroococcaceæ are probably the lowest forms of vegetable life, living either isolated or in colonies, imbedded in a transparent jelly, destitute of cilia, abundant in fresh water (Fig. 8, p. 11).

Palmellaceæ or Protococcaceæ. Green unicellular organisms, occurring in three stages: (1) the *protococcus* form, naked ciliated cells, swimming free in water; (2) the *encysted* condition, also free, but clothed with a cell-wall, and destitute of cilia; (3) the *palmella* condition, associated in colonies which are invested with a common gelatinous envelope (Fig. 59, p. 37). *Protococcus viridis* is an extremely common object in rain-water. It is found very abundantly in the mud where rain-water collects, and in similar situations. In its most ordinary form, each individual consists of a single, nearly spheroidal, cell from ·003 to ·00001 inch in diameter, and varying in colour from bright green to bright red, according to the relative proportion of a green and a red colouring matter diffused throughout the protoplasm or occurring in the form of granules. In this form it multiplies with great rapidity by fission, *i.e.* by simple cell-division; and is also stated occasionally to increase by gemmation or budding. The individual *Protococcus* performs all the functions of an ordinary vegetable cell, respiring, *i.e.* absorbing oxygen and giving off carbon dioxide in the dark, in consequence of the oxidation of its substance, and probably also in the day-time, although the process is then concealed by the opposite process of nutrition, or the decomposition of carbon dioxide and elimination of oxygen, which is effected by the chlorophyll under the influence of sunlight. The change to the active condition takes place in the following way. The protoplasm withdraws itself from the cell-wall at all but two points, where it protrudes through the wall in the form of long vibratile cilia, by the motion of which it is propelled through the water. The cilia are extremely delicate, and are invisible except when moving very slowly, or when artificially coloured by some reagent, as iodine, which, however, kills the plant. In this condition it sometimes loses its cell-wall, and swims about as a naked primordial cell. Eventually, however, it loses its cilia, clothes itself with a coat of cellulose, and becomes quiescent.

In this state it may retain its vitality when dried up, even for years; and will then resume its activity when again placed in water.

Palmella nivalis, appearing suddenly in enormous quantities on Arctic snow-fields, is the substance known as 'red snow.' *P. cruenta* often forms red patches resembling coagulated blood on stones and rocks.

The NOSTOCACEÆ consist of curved moniliform filaments of cells imbedded in jelly, one species, *Nostoc commune*, being common on dry ground. The ordinary small cells are replaced here and there by larger cells known as *heterocysts*, the function of which is unknown. Reproduction takes place by portions of the filaments between the heterocysts becoming detached, escaping from the enveloping jelly, and dividing into fresh filaments. Some species of *Nostoc* are *endophytic*, living within the cells of other living plants.

The OSCILLATORIEÆ are very common objects in running or stagnant fresh water. They consist of cylindrical filaments, enveloped in a gelatinous sheath, sometimes divided by very delicate transverse septa into disc-like cells, which readily separate. The only mode of reproduction known is by the detachment of portions of the filament, known as *hormogonia*, which carry on an independent existence, and develope into new filaments. In both the Oscillatorieæ and the Nostocaceæ the cell-contents are of a bluish-green colour, from the presence of phycocyanin in the cell-sap. The Oscillatorieæ are endowed with a constant oscillating motion of the filaments.

The RIVULARIEÆ form soft greenish-blue lumps of jelly, which swim about in stagnant water, or grow attached to water plants. Within the gelatinous envelope are very slender moniliform filaments of roundish cells, running out at the extremity into a long hyaline hair, the basal cell being a much larger *heterocyst*. Reproduction is effected by special cells separating from the rest, becoming invested in a firm cell-wall, and remaining in this condition for some time as *resting-spores*. A new colony is then produced by cell-division.

The SCYTONEMEÆ are nearly allied to the Rivularieæ, forming branched filaments enclosed in a thick gelatinous envelope.

Sub-class II. PROTOMYCETES.

The cells are isolated or associated in colonies, and do not contain chlorophyll. They are therefore incapable of carrying on an independent existence, and live only in organic fluids, where they occasion putrefaction or fermentation. They are not endowed with cilia, but have in some cases an apparently spontaneous power of motion. The Protomycetes are reproduced by cell-division (gemmation) or free cell-formation. They are divided into two well-marked families :—

The SCHIZOMYCETES, or Bacteriaceæ, are extremely minute unicellular organisms, occurring in enormous quantities in all organic solutions where decay is going on, of which process they are the invariable accompaniment, if not the cause. The number of distinct forms that have been described as belonging to the Schizomycetes is very large ; but to what extent these are different conditions of development of the same organism is still in doubt. They may be conveniently arranged under the following heads, viz.:—

1. *Micrococcus.* Globular and extremely minute.
2. *Bacterium.* Short straight rods.
3. *Bacillus.* Longer straight rods.
4. *Vibrio.* Curved rods.
5. *Leptothrix.* Straight filaments.
6. *Spirillum.* Curved filaments.
7. *Zooglœa.* Colonies of globular cells imbedded in mucilage.

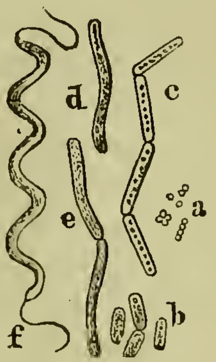

Fig. 380.—Bacteria : *a Micrococcus prodigiosus* ; *b Bacterium Lineola* ; *c Bacillus Ulna* ; *d Vibrio Rugula* ; *e* the same, dividing : *f Spirillum volutans.*

The rods and filaments are characterised by the ease with which they break up into separate segments as soon as they come into contact with the atmosphere, from which circumstance the class has received its name. They multiply in this way, by simple division ; but in the case of *Bacillus*, the formation of endogenous *spores* has also been observed. All the forms except *Micrococcus* and *Zooglœa* are endowed with rapid vibratory motions by means of cilia attached to the extremities, which can only be made out by the highest powers of the microscope, and with the assistance of staining reagents.

The SCHIZOMYCETES usually grow in water, splitting up the nitrogenous compounds which are contained in it into ammonia, which supplies them with nutriment, and other substances which arise as secondary products of decomposition. Such decompositions of nitrogenous substances are known as *putrefaction*, and the chief or sole agent in this decomposition is the organism known as *Bacterium Termo.* Solid nitrogenous compounds which are insoluble in water are rendered fluid by the agency of bacteria. As soon as the nitrogenous substances in the substratum are entirely consumed, the bacteria gradually cease multiplying, and pass over from their motile to their stationary condition, usually secreting at the same time an intercellular substance, and congregating into gelatinous colonies. In this state, when they are known as *Zoogl&oelig;a*, they still continue to grow, divide, and, under certain circumstances, again to become active. Those bacteria which develope in damp air on nitrogenous nutrient substances also form gelatinous masses ; they often produce, as secondary products of their process of assimilation, red, violet, yellow, green, and brown colouring substances.

When water which contains living bacteria is evaporated, a great number of these organisms are carried into the air, and in particular the most minute globular forms, the *Micrococci.* The germs of bacteria which, in consequence, rise into the air whenever putrefying fluids are evaporated, are carried down everywhere by rain, are sucked in with the air in breathing, and hence become causes of putrefaction in all nitrogenous substances exposed to the air, since their vitality is not lost in the atmosphere. Of this nature are many and possibly all causes of putrefaction and the propagators of contagious diseases. These latter are mostly immotile globular bacteria (*Sphærobacteria*), often united together into clusters, drinking-water being usually considered the medium of their propagation. The blood of animals attacked by contagious diseases generally contains, a considerable time before their death, a prodigious number of bacteria—straight, rigid, cylindrical rods which are bent at an obtuse angle in one or two places, extremely slender, and usually not more than from ·004 to ·012 mm. in length. In the intestines, excrements, and vomit of cholera patients are found, at least at the commencement of the attack and possibly as its cause, enormous quantities of organisms of this nature. Under the Schizomycetes must also be included *Leptothrix buccalis*, an organism which always occurs in the mouth, especially in the morning, but is in general without any pathogenous significance. It consists of extremely delicate transparent filaments, which, nevertheless, appear to be composed of separate cells, since they break up into sharply defined pieces simply on being touched. The cube-shaped cells of *Sarcina ventriculi* are commonly found in the gastric juice of man. To this class belongs also the substance known as *Monas* (*Micrococcus*) *prodigiosa*, closely resembling the red corpuscules of the blood, which sometimes appears in prodigious quantities on bread and similar substances. The disease caused by *Achorion Schœnbeinii*, called 'favus,' usually attacks the part of the head of man which is covered with hair, and produces there the characteristic straw-coloured crab's-eye-shaped incrustations; and since its spores grow into the hair, this obstinate disease ends in complete and permanent loss of hair. The spores of *Trichophyton tonsurans* penetrate in enormous numbers into the hairs, make them brittle, and cause them to break off at the skin. All these diseases, as well as others which might be added, are contagious. *Bacillus anthracis* is the cause of 'charbon' in animals; *B. tuberculosis* is supposed to be the pathogenous agent in phthisis; *Micrococcus vaccinæ* is the active element of vaccine lymph; *M. diphtheriticus* is always found in diphtheritic membranes. The foot-rot, the cholera of fowls, and many other diseases which attack man and other animals, are also due to the effects of specific bacteria.

Certain kinds of *fermentation* are also due to these organisms. *Bacillus amylobacter* is capable of acting on starch in a manner analogous to diastase, converting it into glucose; or breaking up it or other carbohydrates into butyric acid, carbon dioxide, hydrogen, &c., and is thus the cause of butyric fermentation. *Micrococcus ureæ* is the ammoniacal ferment of urine, splitting up the urea into ammonium carbonate and hydrogen. The acetic fermentation is due to *Bacterium aceti*, which converts alcohol into acetic acid. Lactic fermentation is due to *Bacterium lactis*, which changes the sugar of milk into lactic acid. The importance of these organisms in the study of pathology cannot be over-estimated.

The SACCHAROMYCETES consist of minute isolated cells, reproduced by the mode of cell-division known as *gemmation*, as well as by endogenous spore-formation. They are not endowed with cilia or with spontaneous motion. They are the sole cause of alcoholic fermentation.

Saccharomyces or *Torula cerevisiæ* is the ordinary *Yeast* of beer, a brownish fluid which possesses the property of causing in any solution which contains sugar the change known as *Fermentation*, that is, the conversion of the sugar into alcohol, which remains in the fluid, and carbon dioxide, which is given off in the form of bubbles. Yeast, when evaporated at a low temperature, is reduced to a powdery mass, which retains for a considerable period its property of fermenting saccharine fluids. Fermentation is prevented by boiling either the yeast or the saccharine fluid, or by previously straining the yeast through a very fine filter, such as porous earthenware ; nor does any change take place if, after boiling the fluid, it is allowed to come into contact only with air which has been passed through cotton-wool. Hence it is concluded that the fermentation is caused by a solid substance contained in the yeast, which cannot pass through the earthenware or cotton-wool. Examined under a low magnifying power, yeast is found to contain a number of nearly spherical transparent granules, averaging about ·0003 of an inch in diameter, each of which is a *Saccharomyces.* Each individual is an ordinary vegetable cell, usually containing a vacuole, but it is doubtful whether there is a nucleus ; and the cells are either solitary or associated in heaps or strings. It consists of carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, potassium, magnesium, and calcium ; the last four in very small quantities. Its chief proximate constituents are (1) a protein-compound analogous to casein ; (2) cellulose ; (3) oil ; (4) water ; the larger part of the mineral substances being contained in the protoplasm. The *Saccharomyces* is the sole cause of fermentation in the sugar, and is believed to be always present in the air in the form of invisible dust. If a small quantity of yeast is added to a large quantity of a clear saccharine fluid, and the fluid kept warm, it will gradually become more and more turbid, and a scum of yeast will collect, containing a prodigous quantity of *Saccharomyces*-cells. The ordinary mode of reproduction is by what is termed *gemmation* (Fig. 381), each cell giving rise to minute protuberances, which grow rapidly, attain the size of the parent-cell, are separated by a septum of cellulose, and eventually become detached, but not generally until they have themselves developed a second generation of buds. They very commonly adhere together in the form of heaps or strings. A second, but rarer, mode of multiplication is the formation of *spores* by *endogenous* free-cell formation, the protoplasm of a cell dividing into usually four masses, each of which surrounds itself by a cell-wall ; and the daughter-cells are eventually set free by the dissolution of the wall of the parent-cell. In order to show that the substances of which the *Saccharomyces* consists, protein, cellulose, and oil, were not present in the nutrient fluid, but have been manufactured by the yeast-fungus out of it, it is best to take a nutrient fluid of definite chemical composition, a convenient one being that known as 'Pasteur's solution.'[1] The power of constructing protein out of such a substance as ammonium tartrate, and the investment of the protoplasm by a continuous coat of cellulose, are the chief properties which determine the *Saccharomyces* to be a vegetable. It allies

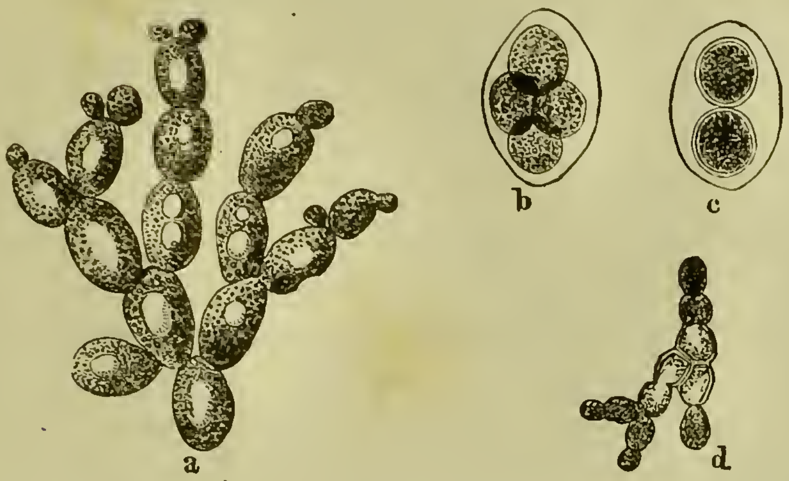

FIG. 381.—Reproduction of *Saccharomyces cerevisiæ* : *a* increase by gemmation ; *b* by endogenous free-cell formation ; *c* two fully formed spores ; *d* a spore increasing by gemmation. (× 1000).

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[1] Potassium phosphate, 2 parts ; calcium phosphate, 2 parts ; magnesium sulphate, 2 parts ; ammonium tartrate, 100 parts ; cane sugar, 1,500 parts ; water, 8,394 parts.

itself to Fungi in containing neither starch nor chlorophyll, and having consequently no power of decomposing carbon dioxide. In the process of fermentation nearly the whole of the sugar is converted into an equal weight of alcohol and carbon dioxide ; but a small quantity of glycerine and succinic acid are also produced ; and one or two per cent. is not yet accounted for, but may perhaps be assimilated by the *Saccharomyces.* It will grow and multiply actively in a solution in which sugar and ammonium nitrate replace the ammonium tartrate ; and in this case the carbon must be obtained from the sugar. Although oxygen is essential to its life, it will live in saccharine solutions which contain no free oxygen, appearing, under these circumstances, to get its oxygen also from the sugar. It will also flourish in solutions in which the ammonium tartrate is replaced by sugar and pepsin, in which case the nitrogen of the protein-compounds must be derived from the pepsin.

The mode of multiplication of *Saccharomyces* by the endogenous formation of spores has led some authors to regard them as the lowest members of the group of ascomycetous Fungi.

Saccharomyces cerevisiæ occurs in two distinct forms, known as 'high' and 'low' yeast. There are also a number of other species, more or less nearly related to one another, some of which accompany other kinds of fermentation, while others are pathogenous in man or other animals. *S. ellipsoideus*, *Pastorianus*, and *apiculatus* occur in the fermentation of wine ; *S. glutinis* causes starch to ferment ; *S. Mycoderma* (*Mycoderma vini*) forms the 'mould' on beer and wine, and also accompanies acetic fermentation ; *S.* (*Oidium*) *albicans* appears to be the cause of the disease known as 'thrush.'

CLASS II. *Algæ.*

Algæ are submerged water plants, growing in fresh, brackish, or salt water, or at least in very damp situations, entirely cellular, and without any distinction of stem and branches, but always containing chlorophyll, and therefore capable of carrying on an independent existence. Reproduction takes place either (1) non-sexually, which may be by simple *fission* or cell-division, as in the case of the desmids and some other lower forms, or by *spores*, which are either motionless, and are then usually *tetraspores* (Fig. 382), formed in groups of four within a sporangium, or *zoospores* (Fig. 82, p. 56, and Fig. 386, p. 254), endowed with apparently spontaneous motion by means of vibratile cilia; or (2) sexually, and then assumes two forms: the union of apparently similar cells, *conjugation* (Fig. 54, p. 32, and Fig. 383, p. 257), or the fecundation of a female cell, *oosphere*, by a male protoplasmic body, *antherozoid*, and the consequent production of an *oosperm* (Figs. 385–387).

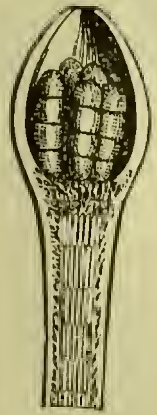


FIG. 382. — Tetraspores of *Corallina cupressina*, enclosed in the tetrasporangium cut open.

Algæ vary very greatly in size, from the microscopic unicellular diatoms and desmids to the gigantic seaweeds like *Macrocystis* (Fig. 391, p. 262), which attains a length of 1,000 feet. The important points of distinction between the different forms lie either in the degree of development of the individual cells, or in the mode in which they combine. Even among the Unicellular Algæ the greatest variety of forms is found, from the rooting spherical cell of *Botrydium* (Fig. 81, p. 55), to the species of *Caulerpa* (Fig. 383) of tropical seas, two feet in length, and simulating the appearance of stem, leaves, and roots. Sometimes the single cell branches copiously, its branches becoming most intimately connected with one another in such a peculiar way that a tissue-like structure is produced, as in *Coleochæte scutata*, and a section through the whole presents the appearance of a number of cell-cavities, where we have actually only protuberances of a single cell. Sometimes these protuberances lie in such regular layers one over another, that a transverse section might be imagined to exhibit one medullary and two cortical layers, as in *Udotea cyathiformis*. The Multicellular Algæ are either filiform, the cells arranged in a row or thread (Fig. 54, p. 32); or the cells form a flat surface or single layer only one cell thick (Fig. 82, p. 56); or, finally, a solid mass of cells in three directions. Within these three classes even a greater variety of form prevails than in the Unicellular Algæ; some of the larger species of *Fucus*, for example, often bearing a resemblance to branched trees. In the massive algæ it is very common for there to be a differentiation to this extent into epidermal and fundamental tissues, that the outermost layers consist of smaller cells with thicker walls, while the interior cells are often much larger, and sometimes of great length. This is, however, correctly described only as a *pseudo-parenchyma* ; there is nothing of the nature of primary parenchyma or cambium ; and the entire process of growth is governed by a single apical cell. True roots provided with a root-cap are also altogether wanting.

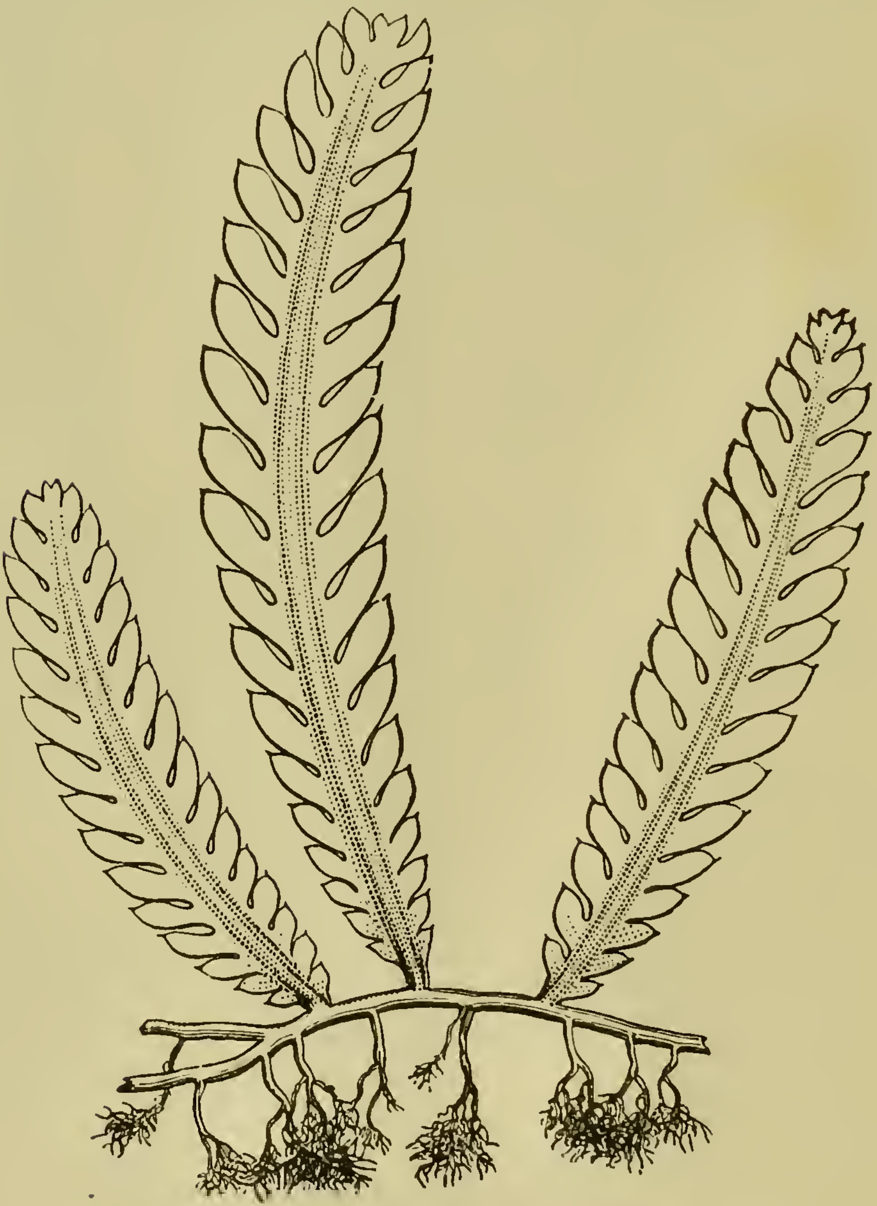


FIG. 383.—*Caulerpa taxifolia,* a marine Unicellular Alga (natural size).

The cell-walls of Algæ usually consist of ordinary unlignified cellulose, which is coloured blue by iodine and sulphuric acid ; but they have a great disposition to be converted into a mucilaginous substance, causing the entire organism sometimes to become surrounded by a gelatinous envelope, while in other cases a stalk-like mass of jelly connects the Alga with others of the same kind, or fixes it to its substratum. Many are calcareous, and the calcium carbonate is, in some cases, as *Corallina*, deposited in the cell wall; while in others, as *Cymopolia*, it is excreted into the intercellular spaces. The cell-walls of the Diatomaceæ form, in consequence of the deposition in them of silica, actual coats of mail, which are not destroyed either by decay or at a red heat. Although the diatoms are at most 0·1 mm. in diameter, these siliceous coatings form strata which are not without importance in building up the crust of the globe, as in the case of emery and infusorial earth (Fig. 38, p. 22, and Fig. 384).

The cells of Algæ often contain starch and oil. The presence of chlorophyll is of special importance; and this is invariable, although often concealed by pigments of various colours. These combinations of colours are remarkably constant in large natural groups. Thus the Diatomaceæ exhibit a yellow colour, the Fucaceæ a brown or olive, and the Florideæ a beautiful rose-red. Both the chlorophyll and the other colouring matters sometimes form granules in the living cells, sometimes broad bands often curved spirally, as in *Spirogyra* (Fig. 41, p. 25), sometimes elegant discs, the forms of which are characteristic of particular genera. It is also not uncommon for the chlorophyll-grains to be imbedded in coloured fluids. On the death of the plant these colouring matters commonly undergo a change, so that, when dried, Algæ seldom retain the beautiful colours of the living plant.

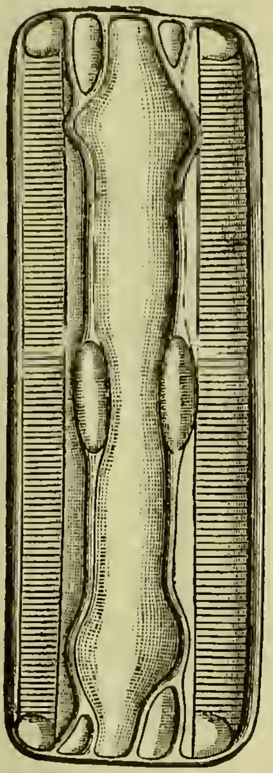


FIG. 384.—*Grammatophora subtilissima*, a diatom (× 1550).

In the formation of zoospores or swarmspores, one or more naked primordial cells are formed by free-cell formation in a particular cell of the parent plant; these become free by rupturing its cell-wall, and then swim about in the water for a longer or shorter time by means of two, four, or a larger number of vibratile cilia with which they are provided. They are microscopic and destitute of a cell-wall; but, after gradually coming to rest, develope a cell-wall of cellulose, and then grow into a new Alga. They occur in both freshwater and marine Algæ, *Vaucheria*, *Œdogonium*, &c. Occasionally two zoospores, one of which exceeds the other in size many times, coalesce, the product of their union being

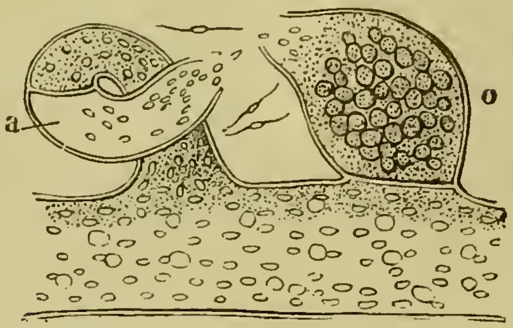


FIG. 385.—*Vaucheria sessilis* : portion of filament with organs of reproduction. The antherozoids, three of which are represented more highly magnified, are escaping from the antheridium *a* into the oogonium *o*. (× 250).

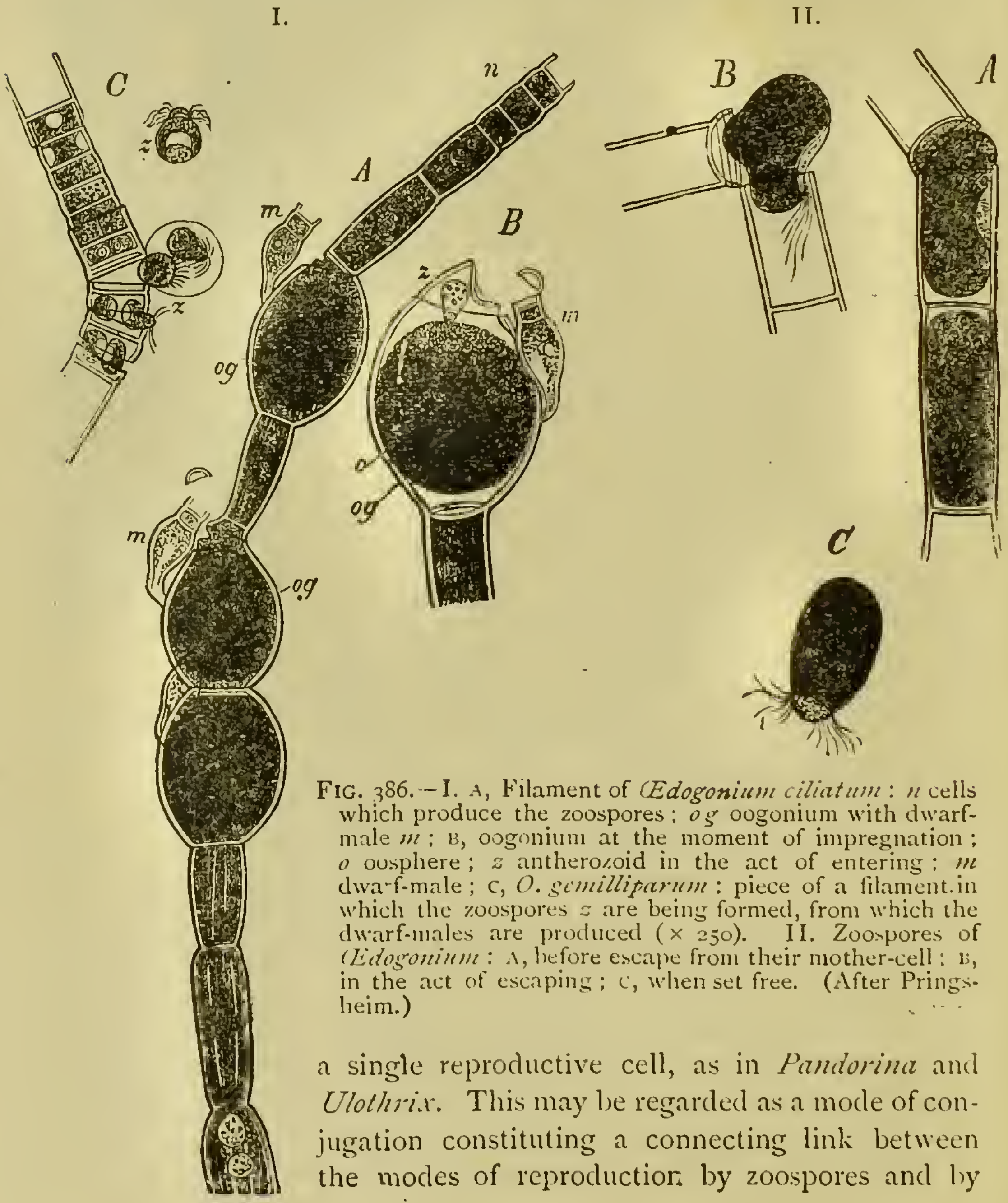


FIG. 386.—I. A, Filament of *Œdogonium ciliatum* : *n* cells which produce the zoospores ; *o g* oogonium with dwarf-male *m* ; B, oogonium at the moment of impregnation ; *o* oosphere ; *z* antherozoid in the act of entering ; *m* dwarf-male ; C, *O. gemilliparum* : piece of a filament in which the zoospores *z* are being formed, from which the dwarf-males are produced (× 250). II. Zoospores of *Œdogonium* : A, before escape from their mother-cell ; B, in the act of escaping ; C, when set free. (After Pringsheim.)

a single reproductive cell, as in *Pandorina* and *Ulothrix*. This may be regarded as a mode of conjugation constituting a connecting link between the modes of reproduction by zoospores and by oospheres. The highest form of sexual reproduction in Algæ is that in which the two cells which share in the process are unlike. The fertilising or male body is in these cases termed a spermatozoid, *antherozoid*, or sperm-cell; the mass of protoplasm which has to be fertilised, female cell, an *oosphere* or germ-cell. The latter are many (often several hundred) times larger than the former. The antherozoids are first formed in a cell which is called an *antheridium*, and the oosphere is the result of the contraction of the protoplasm of a special cell termed the *oogonium*. In *Vaucheria* (Fig. 385) a number of elongated antherozoids are formed in the antheridia, here called 'horns'; these penetrate into the oogonium through an opening formed in its cell-wall at the period of its maturity, and finally reach the oosphere. The latter clothes itself, after fertilisation, with a membrane of cellulose, and becomes the *oosperm*. This assumes the form of a *resting-spore*, which does not germinate at once, but is set free when the alga itself decays, sinks to the ground, remains dormant through the winter, and germinates in the spring. In *Œdogonium* (Fig. 386) the oogonium is a cell of the filament itself. The multicellular antheridium or 'dwarf male' is formed from a peculiar zoospore or *androspore*, which attaches itself to the oogonium. Only a single antherozoid is formed in each cell of the antheridium, which escapes through a slit and forces itself into the oogonium through an opening formed at the same time in its cell-wall, and finally reaches the oosphere, which then developes into an oosperm. In the Florideæ the antherozoids are unprovided with cilia, and are only moved about passively in the water; they attach themselves to a hair-like cell, the *trichogyne*, emptying their contents into it. The result of this impregnation is seen sometimes at the base of the trichogyne (in *Nemaleon*, Fig. 387), sometimes in adjoining cells (in the Ceramiaceæ), sometimes (in *Dudresnaya*) in altogether different branches, on which *cystocarps* are formed, which contain the carposperms.

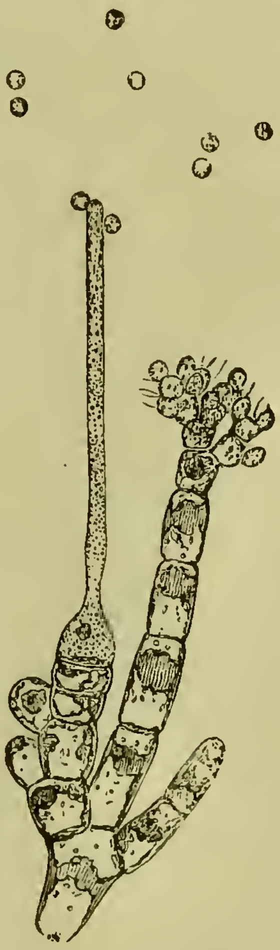


Fig. 387.—Fertilisation of *Nemaleon multifidum*; the globular antherozoids at the apex of the trichogyne.

Algæ are rarely true parasites, although they very commonly inhabit the surface of other plants; they much more often obtain their food by direct assimilation. They may be classified according to their habitat into Fresh-water and Marine Algæ. The former are mostly green, and are found plentifully in any stagnant water or ditch in the spring and summer, and not unfrequently contribute, by their process of vegetation, to the removal of substances decaying in the water. The red, green, and brown marine Algæ are larger and of much greater beauty; some of these live only in the breakers, others only on the quiet bed of the ocean. They very often occur in great masses; the largest of these is the 'sargasso sea,' which occupies several thousand square miles in the Atlantic between 19° and 34° N. lat. and 34° and 36° W. long., the surface of the sea being covered with detached sterile masses of the 'gulf weed,' *Sargassum bacciferum* (Fig. 388).

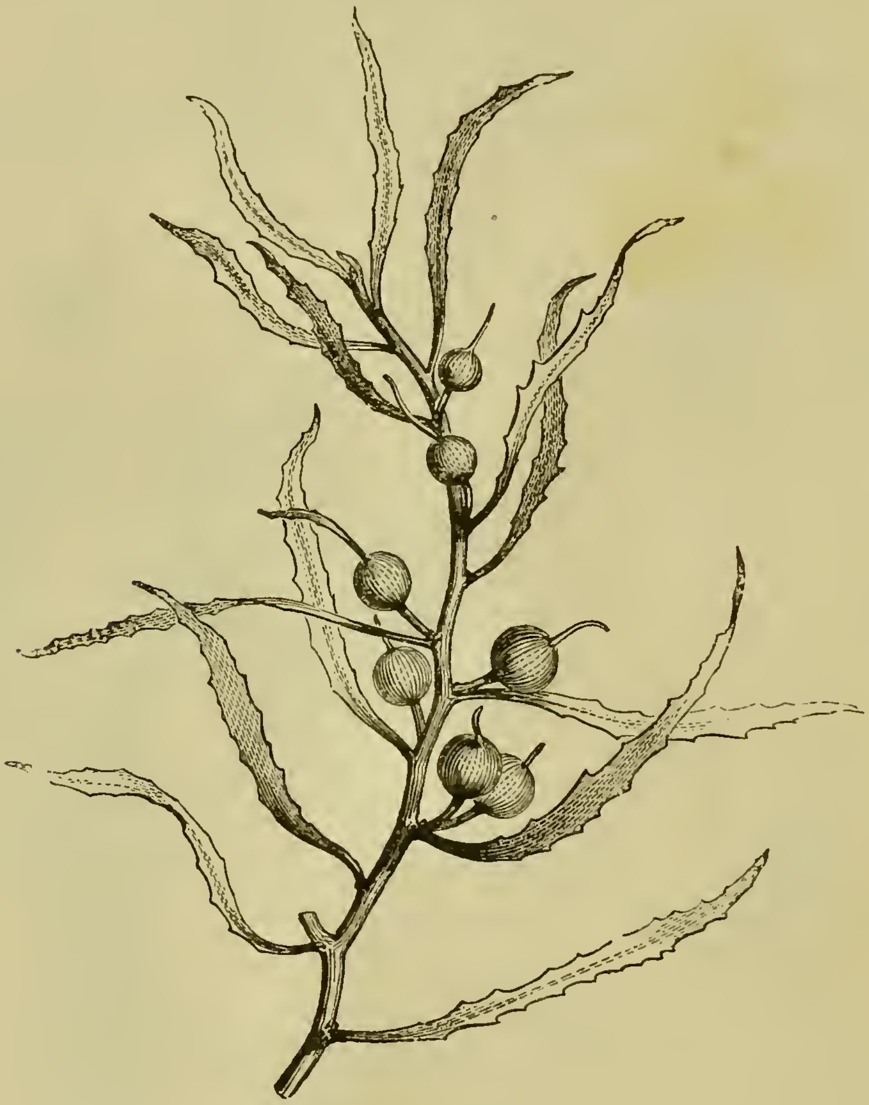


FIG. 388.—The gulf-weed, *Sargassum bacciferum*, with globular berry-like air-bladders (natural size).

The gelatinous substance of the cell-walls gives to several kinds of Algæ the property of being used as articles of diet, such as the species of *Laminaria* and *Ulva* (green laver) on the coasts of Scotland and Ireland, and the 'carrageen moss' which is obtained from *Sphærococcus crispus* and *mammillosus*. The ashes of the larger marine Algæ were at one time largely employed, as kelp, in the manufacture of alkali, and still are for that of iodine. *Gigartina helminthochortos* furnishes 'worm-moss,' but is usually adulterated with other seaweeds.

The most convenient classification of Algæ is into three sub-classes, dependent on their mode of sexual reproduction.

Sub-class I. ZYGOPHYCEÆ.

In the Zygophyceæ the cells which coalesce in the act of fecundation are only with difficulty distinguishable from one another. This mode of reproduction is known as *conjugation*, and the product of coalescence is a *zygosperm*. The conjugating cells may be motionless, or may be possessed of vibratile cilia giving them a power of independent motion, when they are indistinguishable from zoospores.

In the following families of Zygophyceæ, conjugation takes place between naked ciliated masses of protoplasm resembling zoospores.

The ULVACEÆ (Fig. 82, p. 56) are green fresh-water or marine Algæ, in which the thallus consists of a single layer of cells, which is expanded either into the form of a ribbon-like plate or that of a tube. Reproduction is effected by cell-division, or the conjugation of motile ciliated primordial cells.

The CONFERVACEÆ are green or coloured fresh-water Algæ, consisting of branched or unbranched filaments, densely filled with granular chlorophyll. They are among the most abundant vegetable organisms in running, but especially in stagnant water, rapidly filling the water with masses of dark-green filaments. They are reproduced non-sexually by zoospores, but in a few instances conjugation has been observed between motile ciliated bodies resembling the zoospores in everything except their much smaller size.

The SIPHONOCLADACEÆ are fresh-water Algæ composed of a single much-branched cell, varying from a very simple form in *Botrydium* (Fig. 81, p. 55) to one of great complexity in *Caulerpa* (Fig. 383,

p. 252) and similar genera, mostly natives of warm seas. They are remarkable from the large number of nuclei contained in a single cell.

The PANDORINEÆ are fresh-water organisms consisting of a single cell, or of a number united symmetrically into a cell-family enclosed in a gelatinous envelope, each cell being provided with a pair of cilia. Reproduction takes place by cell-division or the conjugation of ciliated cells.

To the Zygophyceæ belong also the beautiful *Hydrodictyon* or water-net, *Pediastrum* (Fig. 58, p. 37), common in fresh water, and *Ulothrix*; but it is difficult to classify these genera more exactly.

The CONJUGATÆ are unicellular or filamentous Algæ, in which conjugation takes place between the ordinary unciliated cells. They comprise three distinct orders :—

1. The *Zygnemaceæ* are fresh-water Algæ of great beauty, consisting of unbranched filaments of cells, often of large size, displaying an evident nucleus, and with the chlorophyll arranged in spiral bands (Fig. 41, p. 25), stars, or a thin axile plate. The process of conjugation, the only mode of reproduction known, may be well watched in *Spirogyra* (Fig. 54, p. 32). When the process is about to commence, the cells of two filaments, lying side by side, put out protuberances, each on the side nearest its neighbour. These protuberances elongate until they meet ; the septum at the point of union disappears, an open channel being thus formed connecting each cell of one filament with a corresponding cell of the other filament. The protoplasmic contents of each of the two cells have, in the meantime, retired from the wall, the chlorophyll losing its spiral arrangement, and have become condensed into an ovoid mass ; then the whole contents of one cell pass through the connecting tube into the other cell. Thus is formed a globular or oval body, the *zygosperm*, which developes two or three coats of cellulose, escapes from the parent-cell by the decay of the filament, and continues for a time in a state of rest, as a so-called 'resting-spore.' After a time, usually in the spring succeeding its formation, the zygosperm germinates, the inner cell-wall bursting through

the outer one, and developing into a filament like the parent. As a rule, all the cells of one of the two filaments pass into those of the other, and not some in one direction, some in the other. The cells of the active filament are also generally somewhat smaller than those of the passive filament; the former may be regarded as a male, the latter as a female filament. Occasionally the cells of one male filament conjugate with those of several female ones; and a process of lateral conjugation has been observed between two adjacent cells of the same filament.

2 The *Desmidieæ* (Fig. 11, p. 12) are unicellular organisms, occurring isolated in fresh water, of symmetrical figure, and containing chlorophyll arranged in symmetrical plates and bands. They vary greatly in form and size, and are very common objects in stagnant and running water, and are among the most beautiful of microscopic objects. They have two modes of reproduction: by division and by conjugation. A good example of the former is afforded by one of the commonest and most beautiful genera, *Cosmarium.* The two somewhat unequal halves of the cell gradually separate from one another, leaving a connecting band, which is ultimately divided midway by a septum. Each half of this band gradually assumes the form of a half-cell, and, together with the half of the parent cell with which it was in connection, constitutes a new individual. Finally, the two individuals completely separate from one another. Conjugation (Fig. 389) is effected by cells which appear as if about to divide approaching one another in pairs; a fracture of the external cell-wall then takes place at the usual line of division, and the contents of each cell, bounded by the parietal utricle, escape, and coalesce into a zygosperm, which assumes a roundish form, and becomes

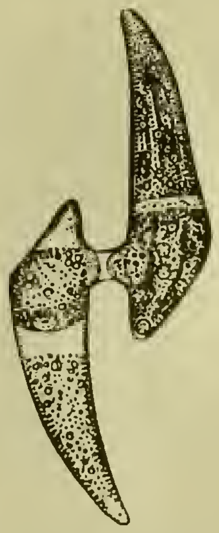


Fig. 389. — Conjugation of *Closterium Lunula*, a desmid (greatly magnified).

invested with an ultimately double coat of cellulose, which is often beautifully covered with spines. Its contents change from green to brown or yellow, and it developes into a new individual after going through a period of rest.

3. The *Diatomaceæ* or *Bacillarieæ* are microscopic unicellular organisms, occurring in great quantities in fresh, brackish, or salt water, and on damp ground, invested with a very hard but thin and transparent siliceous coat, and this again often in a gelatinous envelope enclosing single individuals or groups attached together (Fig. 390). They are always of more or less symmetrical figure; the green colour of the chlorophyll is masked by a brown or olive pigment known as *diatomin*, and they are frequently endowed with apparently spontaneous movements, the source of which is not yet fully explained. Each individual is composed of two similar halves or valves, known as *frustules*, and from the symmetry of their form, and the fineness and regularity of the striations on their thin transparent siliceous coat (Fig. 38, p. 22), they are extremely beautiful microscopic objects. The two halves of each frustule fit into one another like the halves of a pasteboard box. Diatoms are propagated by repeated bipartition; but the diameter of the successive generations gradually diminishes until at length it attains a minimum. This process is then interrupted by the formation of larger cells or *auxospores*, and individuals are produced which reach the maximum size of the species, but in other respects exactly resemble their parent-cells. In these the process of bipartition is then again commenced. In some genera a

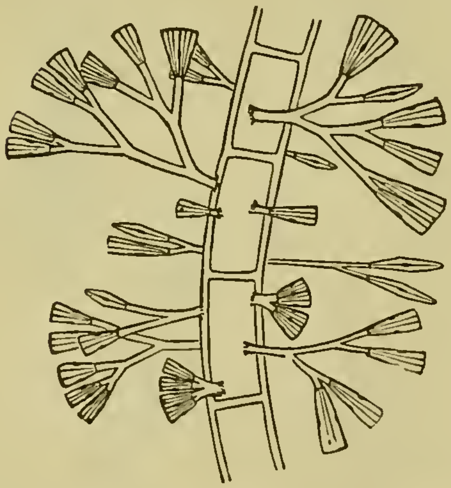


FIG. 390.—*Gomphonema hyalinum*, a social Diatom, attached to a thread of a Conferva (greatly magnified).

true process of conjugation has also been observed, a zygosperm being produced as the result of the coalescence of two different individuals which have previously been enclosed in a gelatinous envelope.

Sub-class II. OOPHYCEÆ.

In this sub-class we have a distinct advance in type from the Zoophyceæ in a distinct differentiation of the sexual cells. The male element is always a primordial ciliated mass of protoplasm, an *antherozoid* or spermatozoid; the female element or *oosphere* is contained within a simple cell or *oogonium*, and the product of fertilisation is known as an *oosperm.* The group consists of several families not closely connected with one another genetically.

In the VOLVOCINEÆ each family consists of a colony of cells or *cœnobium*, which, in the case of *Volvox globator*, a common very beautiful microscopic object in the standing watter of pools, is nearly globular, and swims about with great velocity. Its appearance is that of a transparent membranous hollow sac studded with green points, and carried about by the motion of a large number of vibratile cilia, which project through the common envelope of the cœnobium. A pair of these cilia is attached to each of the green internal corpuscules, which resemble zoospores. Each of these bodies is a young individual, which developes into a new colony within the parent-colony, the daughter-colonies finally escaping by the dissolution of the common semi-mucilaginous envelope. A second non-sexual mode of reproduction is by the formation of resting-spores. *Volvox* is also reproduced sexually by the formation within the colony of male and female cells, antheridia and oogonia, impregnation taking place within the common envelope, from which the fertilised oosperms finally escape.

The VAUCHERIACEÆ or Siphoneæ present a certain resemblance to the Siphonocladaceæ, the whole organism consisting of a single, often much branched and greatly elongated cell, undivided except when the sexual organs are about to be formed. The mode of reproduction is well illustrated in *Vaucheria* (Fig. 385, p. 254), several species of which form light green carpets on damp ground. Portions of the filaments become marked off as oogonia, and other portions near them as antheridia in the shape of horns or birds' heads. When ripe, the antheridia discharge their cell-contents in the form of numerous spindle-shaped antherozoids, moving actively by the help of a pair of cilia. In the meantime an orifice has been formed in the beak of the oogonium; some of the antherozoids, entering here, reach the oosphere, which then becomes an oosperm by investing itself with a coat of cellulose. *Vaucheria* is also reproduced by resting-spores, and by zoospores of a large size, beautifully surrounded by a fringe of cilia.

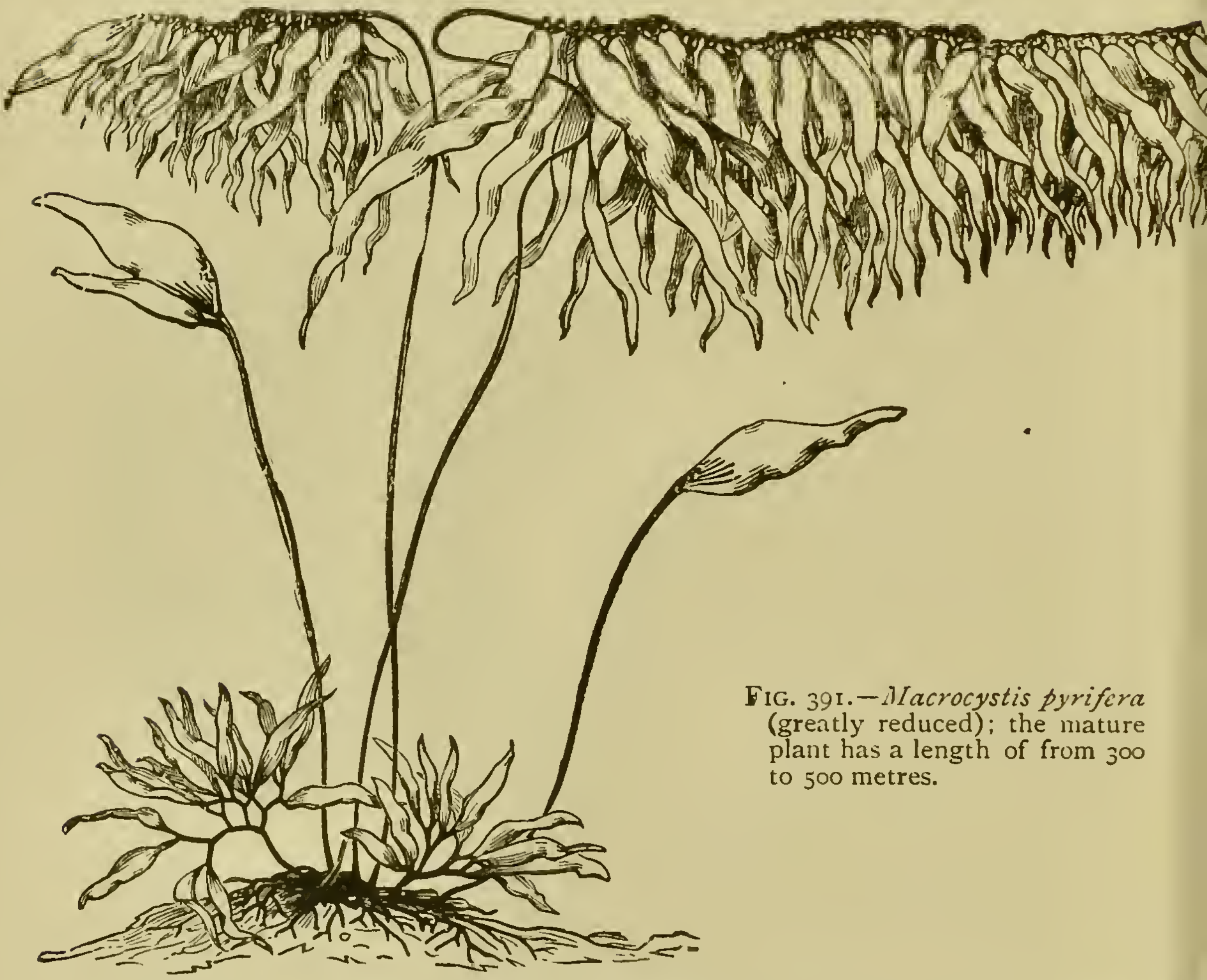


FIG. 391.—*Macrocystis pyrifera* (greatly reduced); the mature plant has a length of from 300 to 500 metres.

The ŒDOGONIACEÆ comprise the genus *Œdogonium* (Fig. 386, p. 254) of fresh-water Algæ. The sexual reproduction consists in the ordinary fertilisation of oospheres by antherozoids; non-sexual reproduction by zoospores (II. A, C) of large size and great beauty, furnished with a tuft of cilia at one end. Characteristic of *Œdogonium* are the *androspores*, resembling minute zoospores (I. A, C), which fix themselves to a definite spot of the female plant, on or near the oogonium, where they germinate, producing very small male plants, the 'dwarf males' or *micrandres*, each consisting only of a single antheridial cell, which gives birth to ordinary antherozoids. The cells of *Œdogonium* present a remarkable appearance from the phenomenon known as 'intercalary surface growth' (II. B), in which a number of annular deposits of cellulose are formed in succession below the upper septum of each cell, giving the appearance of a series of caps.

The PHÆOSPOREÆ are olive or brown seaweeds, frequently of gigantic size (Fig. 391), with a foliaceous shrubby, often, much-branched thallus, which is sometimes coriaceous. The only mode of reproduction at present known in them is by means of zoospores.

The FUCACEÆ are large brown or olive-coloured seaweeds, often many feet long, as in *Sargassum* (Fig. 388, p. 256), and of a cartilaginous texture, forming leaf-like or stem-like *fronds.* They are attached to stones [or other Algæ] by a branched attachment-disc. Their branches, which are often beautifully dichotomous, all lie in one plane, or can be reduced to one without violence to the plant. From the dead plant cold fresh water extracts a fine buff pigment. They very commonly form air-cavities in the interior of the tissue, or occasionally elevated on distinct stalks, as in the gulf-weed, which swell outwards like bladders and serve as swimming-bladders, as in the common bladder-wrack, *Fucus vesiculosus* (Fig. 392). The thallus of

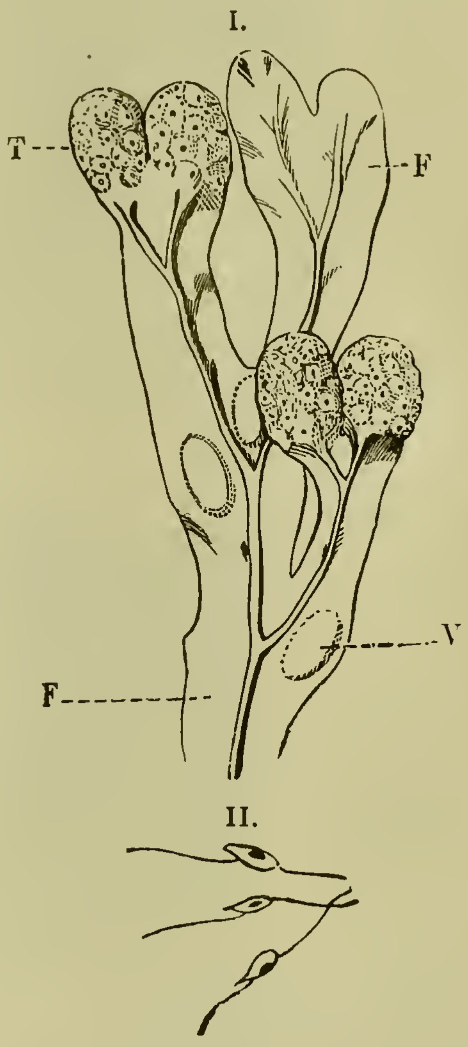


FIG. 392.—*Fucus vesiculosus* : I. F thallus ; T fructification ; V air-bladder (natural size). II. antherozoids (greatly magnified).

the frond is frequently highly developed, and, though strictly cellular, displays a distinct cortical layer. This swells up greatly and becomes slimy in fresh water. The sexual cells are in distinct chambers or *conceptacles* in the same or different individuals. The female conceptacles (Fig. 393 II.) are at first lined with filaments, some of which remain permanently in that condition, and are known as *paraphyses*; they sometimes project through the opening of the conceptacle. Others enlarge into sacs, the oogonia, the protoplasm of which divides into two, four, or eight oospheres, of comparatively large size. In the male concep-

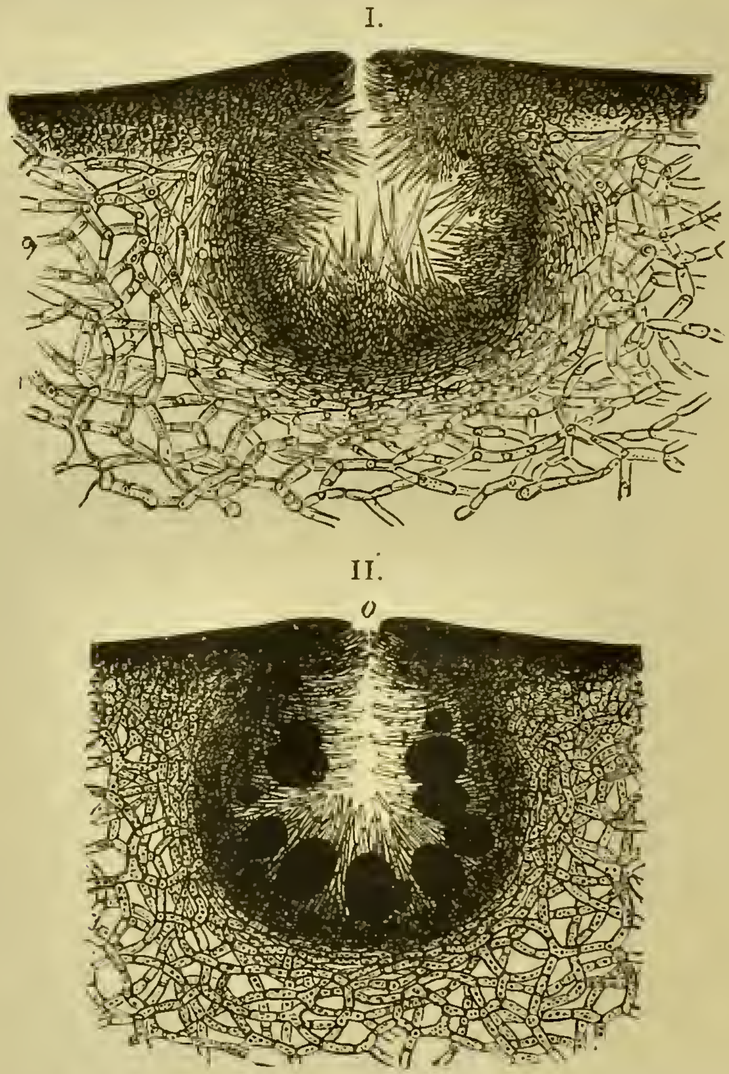


Fig. 393.—*Fucus vesiculosus*: I. Section of male conceptacle, with branched hairs bearing the antheridia. II. The same: section of female conceptacle, with oogonia; *o* mouth through which the oospheres escape. (After Thuret).

tacles (I.) similar filaments develope into branched sacs, the antheridia, from which escape the very minute antherozoids. In some instances oogonia and antheridia are found in the same conceptacle. When ripe, both organs discharge their contents through openings of the conceptacles into the surrounding water. Here a large number of the minute motile antherozoids crowd round the oospheres, coalescing with them, and thus impregnating them and inciting them to develope into oosperms. This process is indicated by the discharge from the mouths of the conceptacles of a drop of an orange fluid. No non-sexual mode of propagation is known in the Fucaceæ.

Sub-class III. CARPOPHYCEÆ.

In the Carpophyceæ the male element is a motile or immotile antherozoid. The female organ containing the oosphere is a multicellular or occasionally unicellular body, the *carpogonium* ; the result of impregnation is a *carposperm*, enclosed in a more or less complicated structure, the *cystocarp*. Except in the simplest forms, other cells besides the actual male and female cells take an indirect part in the process of impregnation, which is hence frequently a complicated one.

The COLEOCHÆTEÆ are small green fresh-water Algæ, forming disc-like or hemispherical patches on submerged water-plants, the sides of aquaria, &c., some of the cells of which are prolonged into long hairs. The carpogonium contains only a single carposperm, and the cystocarp is of simple structure. There is also a non-sexual reproduction by zoospores.

The FLORIDEÆ are marine, rarely fresh-water, Algæ, often of great beauty, including all the red sea-weeds. The red colouring matter, known as *rhodospermin*, is soluble in cold water, and exhibits beautiful phosphorescence. In the *corallines* of our coasts the frond acquires a stony character from the deposition of carbonate of lime. The Melobesiaceæ are small flat incrustations on marine rocks. The thallus or frond of the higher forms is termed *monosiphonous* or *polysiphonous* according as it consists of a single or of several parallel filaments of cells, and a rudimentary differentiation is exhibited between an epidermal layer and internal spongy pseudo-parenchyma. No zoospores are known in the Florideæ; non-sexual reproduction takes place by *tetraspores* (Fig. 382, p. 251), collections of four spores formed by a double bipartition of the contents of the parent-cell or *tetrasporangium*; these are often formed on metamorphosed branches of the frond known as *stichidia*. The antherozoids are motionless unciliated primordial cells, which are carried passively by currents of water to the apex of a long hair-like tube, the *trichogyne* or trichogonium, a prolongation of the cell which contains the oosphere, sometimes carried by a special lateral row of cells, the *trichophore* (Fig. 387, p. 255). The oospheres are produced in other cells near the trichophore. In the most complex forms, such as *Dudresnaya*, the cystocarps are even formed on different branches from the trichophore, and a single trichogyne may assist in the production of a number of cystocarps. A still more complicated process has recently been described in the case of some Florideæ, consisting in a double process of impregnation, first of the oosphere within the carpogonium by an antherozoid, secondly of one or more 'auxiliary cells' by the carposperm, the auxiliary cell thus fertilised finally developing into the cystocarp. The carposperms are usually more or less imbedded in a jelly within the cystocarp; they are either solitary, or are collected into a larger or smaller mass, known as a 'nucleus.' Florideæ are either monœcious or diœcious. The fronds of many species, as *Callithamnion*, display a continuity of protoplasm.

Class III. *Fungi.*

The elements of which the vegetative parts of Fungi that do not subserve the process of reproduction consist, are *hyphæ*, or filaments of cells destitute of chlorophyll, which usually branch repeatedly by lateral ramification, and grow only at their apices. In the simplest fungi the entire vegetative portion consists of a single undivided cell; while in the Mould-fungi it is composed of a single often much branched filament of cells. Even in the highest forms the filaments either run parallel to one another, or in an irregularly complicated mass, but often forming structures of an externally definite form characteristic of particular species. Sometimes the hyphæ are compacted at particular parts into a dense parenchymatous structure, known as a *pseudo-parenchyma*, as in the larger fungi, of which it forms the main mass. The various modes of reproduction in Fungi are closely analogous to those in Algæ. Non-sexual reproduction takes place either by motile ciliated *zoospores*, or by unciliated *spores* of various kinds, which are termed, according to their mode of origin, *basidiospores*, *ascospores*, *uredospores*, *teleutospores*, &c. Sexual propagation is effected by *conjugation*, or by the fecundation of a female *oosphere* by motile *antherozoids.* A more distinct *alternation of generations* is displayed in some classes of Fungi than in Algæ, and in the Lichens we have the most remarkable instance in the vegetable kingdom of the singular phenomenon of *symbiosis* or commensalism.

The cell-wall of fungi consists of cellulose, which, however, is only very rarely coloured blue by iodine and sulphuric acid, and is therefore considered a special modification, under the name *fungus-cellulose.* Very often the outer layers of the cell-wall swell up and pass over into a gelatinous or mucilaginous condition. The cells of fungi contain neither starch-grains nor chlorophyll; their characteristic contents are a fatty oil. Calcium oxalate is very commonly found on the surface of the cells, very rarely in their interior.

The thallus of fungi consists of two principal parts, the *mycelium* and the *fructification.* The former is developed at once on germination, and either consists of simple hyphæ, or forms loose flocculent masses, branching bundles, pellicular expansions (as *Penicillium* when growing on fluids), or, finally, compact tuberous masses, the *sclerotia*, as in ergot.

The *fructification* is, as a rule, the most conspicuous part of the fungus, and is popularly regarded as the whole, as in the mushrooms. *Fertile hyphæ*, consisting of only a single filament, usually erect, are distinguished from true fructifications of a compound structure.

In the fertile hyphæ the terminal cells of the principal filament and its ramifications become the mother-cells of the reproductive cells or spores, their growth as a rule then ceasing. A fresh growth of the lower portion, however, frequently begins after the ripening of the first spores, which soon again terminates with a new formation of reproductive organs, the process being sometimes repeated after a time. The fructification varies greatly in its external form; but the production of spores is almost always limited to a particular part, the *hymenium*, which assumes very different forms in the different groups.

Reproduction by *spores* is by far the most common mode among fungi. The spores, however, vary greatly in their form and mode of formation; in some species two, three, or even four forms have been observed, forming a single cycle of development. Their mode of formation is of three principal different kinds:—

1. By *Division*; *i.e.* by the contents of a *sporangium* breaking up entirely into spores (Fig. 395), or being transformed by segmentation into a *sporidesmium*.

2. On *basidia*; *i.e.* on the apex, or on the more filiform or pointed protuberances, *sterigmata*, of special cells. Such spores are called *basidiospores*, acrospores, or ectospores; and they may either be formed simultaneously or may become detached successively. The former mode occurs in the Agaricini (Fig. 400 II., p. 280); the latter in *Penicillium* (Fig 1, p. 7). Those that become detached in succession, or abstricted, usually form threads, the younger spores placed on the apex of older ones, and the oldest on the basidium. In a few cases, as *Cystopus* and *Peronospora*, sporangia are formed instead of spores on the basidia. Spores which become abstricted in this way from the apex of filaments have been termed *conidia*; if formed in special receptacles or *pycnidia*, they are *stylospores*.

3. In *asci* or thecæ (Fig. 404, p. 282). The spores, here called *ascospores*, are usually formed simultaneously in definite number (in most species eight), in the interior of a sac-like cell, the ascus, which they do not entirely fill up. The asci are usually surrounded by *paraphyses*, *i.e.* unbranched unicellular or multicellular hairs which are formed beside them, usually in large numbers and running in the same direction. Special receptacles in which asci are formed are called *perithecia* (Fig. 403, p. 282).

The zoospores or swarmspores break through the wall of the cell in which they are formed, and which is called a *zoosporangium*; and then swim about for some hours, or even days, as if endowed with voluntary power of motion, by means of their vibratile cilia; after which they become fixed and develope into new plants (Fig. 399,

p. 275). The greater number of spores, however, are not endowed with motion of this kind. In some instances they germinate immediately after attaining maturity; in other cases, where they have thicker coats, only after a definite longer time, so that they appear especially adapted for hibernation, and are termed *resting-spores*. Differences also exist in the mode of germination, many spores developing at once into a new plant, while others first produce spores of a second order, or *sporidia*, which then put out sacs or *pro-mycelia* (Fig. 400 IV., p. 277), and these either repeat the same process or develope into perfect plants.

Sexual reproduction by means of the fecundation of *oospheres* by antherozoids is much less widely distributed among Fungi than among Algæ.

Fungi may be conveniently divided into three sub-classes, dependent on their mode of sexual reproduction, and to a certain extent parallel to those of Algæ. But to these must be added a fourth sub-class, altogether anomalous in structure, and the retention of which in the class of Fungi is not altogether free from doubt, viz.:—

Sub-class I. (?) MYXOMYCETES.

The Myxomycetes (Fig. 394) are distinguished from all other plants by the fact of their cells being without a cell-wall during the whole of their vegetative period. It is only when their protoplasm comes to rest, or their growth has ceased on the formation of the fructification, that the protoplasm breaks up into small cells provided with a cell-wall, but not forming a true tissue. They live on decaying and putrefying vegetable substances. In its membraneless condition the mass of protoplasm, or *plasmodium*, displays an extraordinary motility; and then, independently of the currents in its interior, the whole mass creeps over or in its substratum with a remarkable amœba-like motion. The plasmodium is of a slimy or creamy appearance, and contains a number of net-like anastomosing channels, along which move constant currents of protoplasm, carrying foreign bodies, as spores, granules of starch, &c. But when the plasmodium passes over into the fructifying state, it comes to rest, and breaks up into large receptacles or sporangia, filled with small spores, formed by free cell-formation, and often accompanied by a reticulation of thin-walled tubes opening into one another, a hair-like weft termed a *capillitium.* Round each of these tubes there frequently runs a spiral thickening band. In the simplest forms, as *Dictyostelium*, the spores are not enclosed in a sporangium. The contents of the spore, now provided with a cell-wall, break up on germination into a number of zoospores, known as *myxamœbæ*, provided with a nucleus and vacuole, and endowed with a remarkable amœboid motion, due to peculiar retractile appendages known as *pseudopodia.* These swarming bodies multiply by division during two or three days; and then a new process begins, two or more coalescing into a homogeneous mass of protoplasm or plasmodium, which again moves about in an amœboid manner. The plasmodium often creeps about for the space of a foot, the motion being caused by the projection at its margin of arm-like protuberances, which increase in size by fresh masses of protoplasm flowing into them. When this takes place for some time in one direction, the whole plasmodium has in this way shifted its place. These processes usually occupy a few hours; in the so-called 'flowers of tan,' *Æthalium septicum*, one or two hours is sufficient for the still motile plasmodium to become changed into sporangia. When the vital conditions are unfavourable, the myxamœbæ

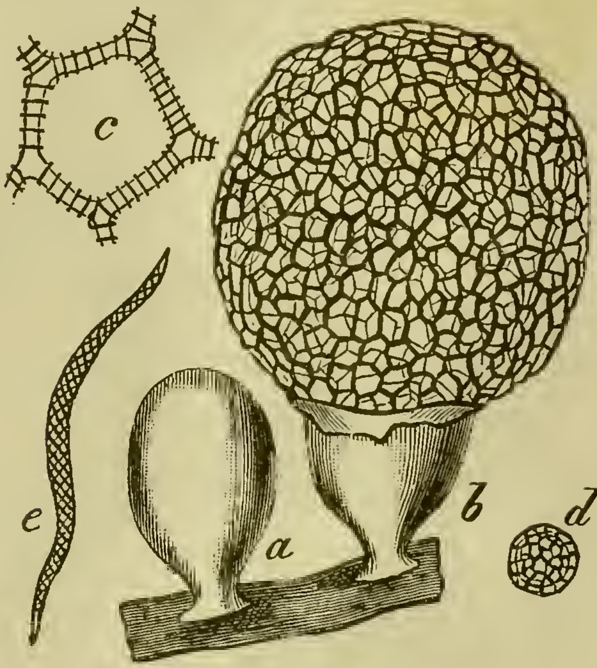


FIG. 394.—*Arcyria incarnata*: *a* closed; *b* dehiscent sporangium with the expanded capillitium (× 20); *c* a portion of the capillitium (× 200), *d* spore (× 400); *e* thread of capillitium of *Trichia clavata*, with spiral thickening.

and the young plasmodia become surrounded by a membrane, or encysted, and, if kept dry, remain in this condition for months without losing their power of life; when placed in water they recur to the motile condition. Mature plasmodia pass into the resting state when the amount of moisture or the temperature is low, forming a sieve-like plate or irregular tuberous body, and finally break up into a large number of round or polyhedral cells of a diameter of 0·025 to 0·033 mm., and of a waxy or brittle texture. When placed in water the cell-walls which had been formed are again absorbed, and the plasmodia re-assume their motile condition.

Sub-class II. ZYGOMYCETES.

In this sub-class the mycelium consists of a single branching filament, which is septated only when about to produce organs of reproduction. Non-sexual reproduction takes place by motionless *spores* enclosed in a *sporangium*, sexual reproduction by the *conjugation* of two branches of the mycelium, and the consequent production of a *zygosperm*. The Zygomycetes include only one well-marked family.

The MUCORINI (Figs. 395, 396) are common mould-fungi, growing on living plants, decaying vegetable substances, or the surface of organic solutions. In *Mucor*, one of the commonest forms of mould, the spores are produced within *sporangia*, roundish heads borne at the extremity of filaments which rise vertically into the air from the hyphæ, and which are known as *sporangiophores*. The wall of the sporangium is rough from minute particles of calcium oxalate. The sporangium is easily ruptured, dispersing the spores; the greater part of its wall then disappears, but a small collar frequently adheres to the filament. The cavity of the filament does not communicate with that of the sporangium, but is separated from it by a partition which bulges into the cavity of the sporangium, forming a central pillar or projection, and termed the *columella*. The spores, on germinating, give rise to ordinary unseptated mycelial filaments. From these the sporangiophores are given off

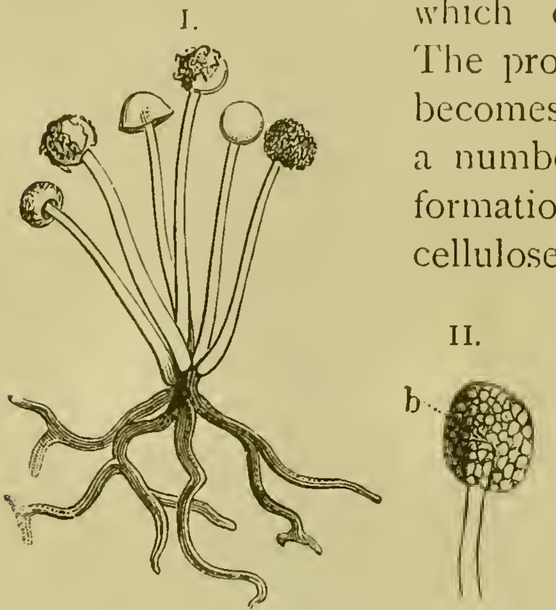


Fig. 395.—*Mucor mucedo*: I. an entire plant with six sporangia in different stages of development (strongly magnified); II. single sporangium with spores *b* (× 200).

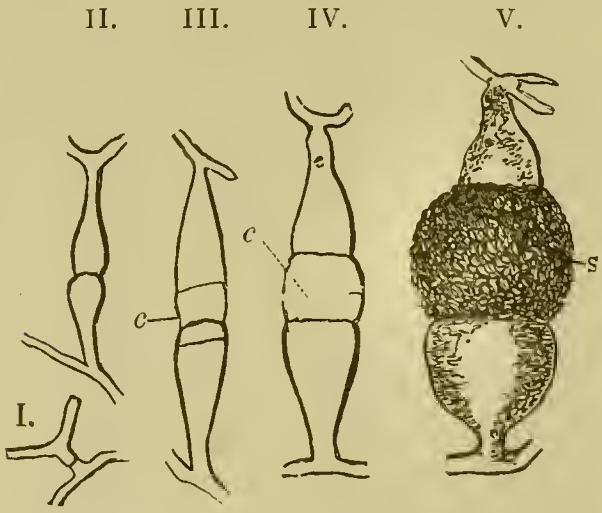


Fig. 396.—Formation of the zygosperm of *Mucor mucedo*: I.-V. successive stages of development; V. *s* the mature zygosperm (× 60).

vertically; the free end dilates into a rounded head which developes into the sporangium, and is separated by a septum which constitutes the columella. The protoplasm in the sporangium becomes gradually separated into a number of masses by free cell-formation, each of which secretes a cellulose coat, and becomes a spore. In addition to the ordinary spores, interior non-sexual reproductive bodies, or *chlamydospores*, are sometimes formed within the mycelial filaments. *Mucor* is also propagated sexually by conjugation, *i.e.* by the production of *zygosperms*. When two filaments come into contact, each puts out, in the direction of the other, a cylindrical protuberance resembling the filament itself (Fig. 396). These two protuberances become closely adpressed to one another by their ends, and grow into a club-shaped body, in which a quantity of protoplasm collects. When both have attained a certain size, a *conjugating cell* (*c*) becomes separated at the upper end of each, the two conjugating cells being usually of unequal size; the partition-wall between the two soon disappears, and they unite to form the zygosperm. The cell-wall of the zygosperm becomes separated into two layers, an outer one of a darker hue, cuticularised, and often spiny, the *exospore*, and an inner colourless layer of pure cellulose, the *endospore*. The germination of the zygosperm, which takes place only after a period of rest, resembles that of a spore.

The CHYTRIDIACEÆ are very minute organisms of simple structure and uncertain position, parasitic on or very frequently endophytic in flowering plants, algæ, or other fungi. They produce zoospores, which have often been mistaken for those of the host; and they are said also to be reproduced by conjugation. Nearly allied to them are the PIPTOCEPHALIDÆ.

Sub-class III. OOMYCETES.

The mode of sexual reproduction is here, as in the Oophyceæ, the fecundation of an *oosphere* contained in an *oogonium*, by motile ciliated antherozoids, and the consequent production of an *oosperm*. The non-sexual reproductive organs are either motile *zoospores* or motionless *conidia*. On germination the oosperms give birth either to sporangia, to conidia, or to zoosporangia, thus displaying an alternation of generations.

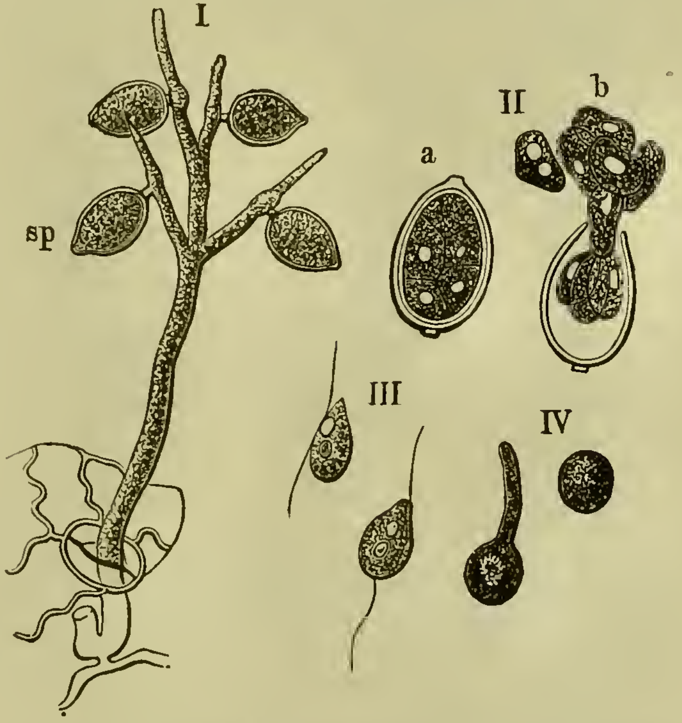


FIG. 397.– *Phytophthora infestans*: I. a fertile branch growing out of a stoma, bearing four mature conidia; II. zoospores emerging from a conidium; III. escaped zoospores; IV. zoospores germinating. (I. × 200; II.–IV. × 300.)

The PERONOSPOREÆ are fungi parasitic on living Phanerogams, the tissues of which they attack and destroy. The mycelium, ramifying through the tissue of the host, puts out *conidiophores* (Fig. 397), erect branches, appearing above the surface of the host, which again branch and bear the *conidia*. These are either simple spores, which, on germinating, directly produce a mycelium, or they are *zoosporangia*, their contents breaking up into *zoospores*, each of which gives birth to a mycelium. The process of sexual reproduction is nearly identical with that in the Saprolegnieæ (Fig. 398). The female cells or *oogonia* are spherical, full of protoplasm, and usually terminal. Their protoplasm collects into one or more globular masses, the *oospheres*, which have at first a smooth surface, but no cell-wall. During the formation of the oogonium slender branches from its pedicel or from neighbouring filaments grow out towards it. The upper end of one or more of these branches becomes firmly adherent to the oogonium, no longer grows, swells up somewhat, and becomes separated by a septum into an independent cell, the fertilising *antheridium*. As soon as both the oogonium and antheridium have attained their full size, and the oosphere is at least in process of formation, the antheridium puts out one or more beak-like protuberances, the *fertilising tubes*, which pierce the wall of the oogonium. In the Saprolegnieæ these tubes give way at the end, and inject their contents—minute motile bodies scarcely ·002 mm. in size, the *antherozoids*—into the oogonium. In the Peronosporeæ, on the contrary, the fertilising tubes do not burst, but only touch with their apex the oospheres, which then become covered with a cell-wall of cellulose, and develope into the unicellular *oosperms*. The germinating oosperm again gives rise, after a long period of rest, to

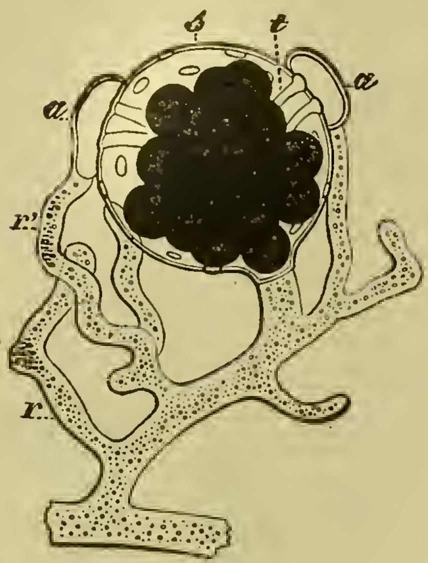


FIG. 398.—Process of impregnation of *Saprolegnia monoica* : *a a* antheridia ; *t* fertilising tubes which penetrate into the oogonium *s* : *r r* mycelial filaments.

a mycelium, which bears first conidia, and afterwards the sexual organs. Or in other instances the contents of the oosperm break up into zoospores. Again, the germinating oosperm may produce a germinating filament or *pro-mycelium*, from which the new mycelium is developed. The mycelium of *Cystopus*, an extremely common parasite, especially on Cruciferæ, is provided with numerous organs called *haustoria*, which penetrate the cell-walls of the host, and extract the nutriment for the use of the parasite. The Peronosporeæ are among the most destructive parasites to living plants. *Phytophthora infestans* (Fig. 397) is the well-known

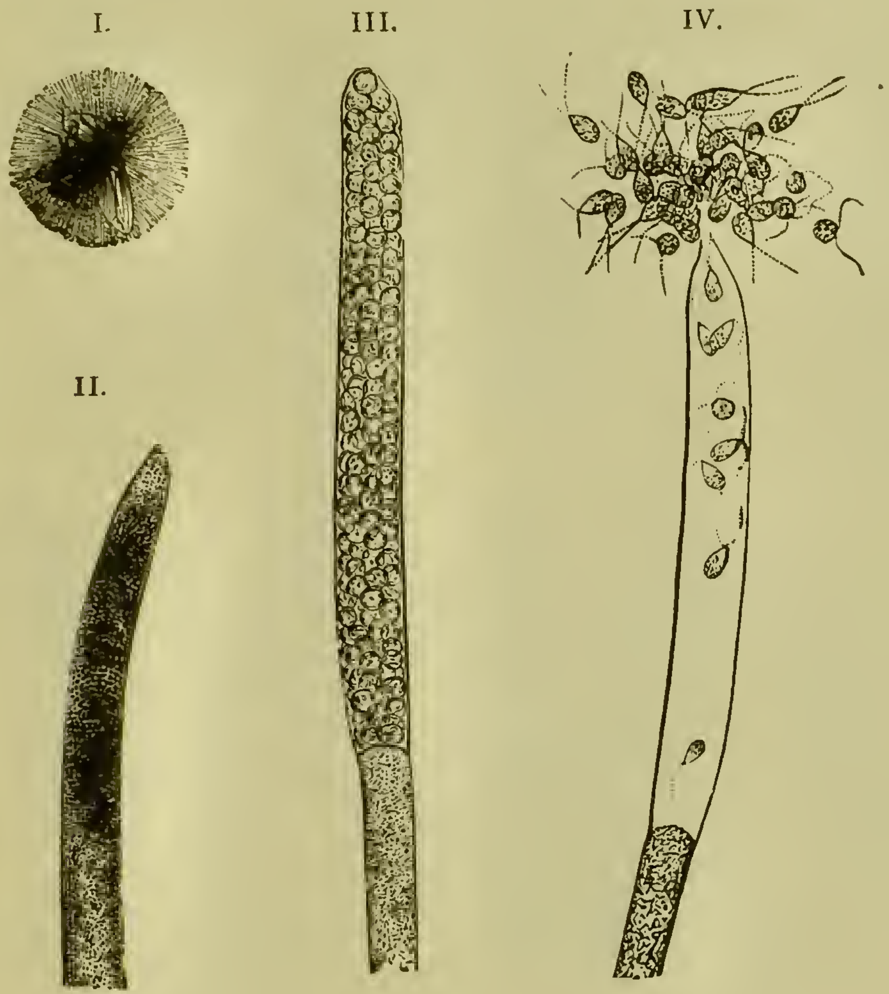


FIG. 399.—I. Fly which has putrefied in water and become surrounded by the filaments of *Saprolegnia ferax* (natural size); II. end of one of these filaments (greatly magnified); III. protoplasm of the end of the filament collecting into globular masses; IV. biciliate zoospores produced from the protoplasm escaping from the cell (× 300).

potato-blight. The zoospores penetrate into the mesophyll of the leaves through the stomata, especially in wet weather, and grow rapidly; the mycelium rapidly depriving the leaves of their food-supply, causes decay of the haulm and tubers. (See also p. 230.)

The SAPROLEGNIEÆ (Figs. 398, 399) are nearly allied to the Peronosporeæ, but grow for the most part in water, and chiefly on the dead bodies of insects. The two modes of reproduction, sexual and non-sexual, are similar, but many of the Saprolegnieæ are diœcious, the male and female organs being produced only on different plants. *Parthenogenesis*, or the production of fertile oosperms without the action of antherozoids, occurs in *Saprolegnia* and *Achlya*. *Saprolegnia ferax* is the parasite so extremely destructive to salmon.

The ENTOMOPHTHOREÆ form a small group, apparently intermediate between the Saprolegnieæ and Mucorini. To it belongs *Empusa muscæ*, which covers with a flocculent growth the bodies of flies decaying in water.

Sub-class IV. CARPOMYCETES.

In some families belonging to this class the fructification is a *cystocarp*, corresponding, to a certain extent, to that in the Carpophyceæ, and results from the action of a male organ or *pollinodium* on a female organ or *carpogonium*. In others no sexual mode of reproduction is known, and these are only referred hypothetically to this sub-class. Non-sexual propagation takes place by motionless spores or *conidia*; zoospores do not occur.

The ÆCIDIOMYCETES (or Hypodermiæ) are made up of the two families Uredineæ and Ustilagineæ, and are noteworthy as displaying the most remarkable illustration of *alternation of generations* in the vegetable kingdom.

The most familiar instance of this alternation of generations occurs in some UREDINEÆ, as in the common 'rust' of corn, *Puccinia graminis* (see also p. 226). The resting-spores, or *teleutospores* (Fig. 400, II., III.), of this Fungus—thick-walled spores situated at the apex of filiform *basidia*, either singly or in pairs—produce on germination a *pro-mycelium* which bears three or four *sporidia* (Fig. 400, IV.). These produce first *spermogonia* (Fig. 400, I.), narrow-necked sacs containing minute bodies, the *spermatia*, which are believed to be male organs that have lost their function, no female organs having at present been detected in these fungi ; then cup-shaped organs which were at one time described as a distinct species under the name *Æcidium*. The *æcidiospores* formed in these organs give rise to resting-spores, or produce the *uredospores* (Fig. 400, II.), out of which nothing but fresh uredospores arise. The form of the Uredineæ which produces the uredospores was also formerly regarded

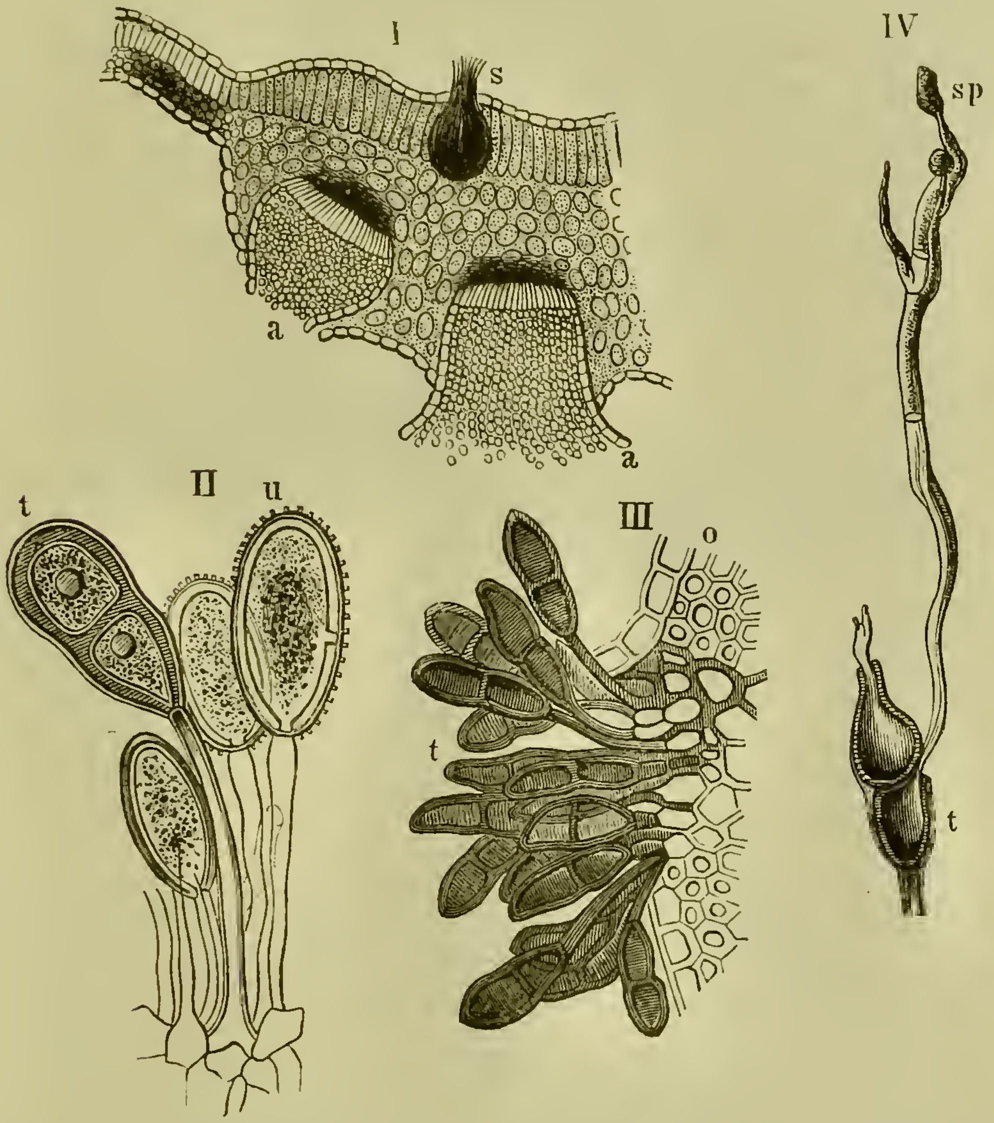


FIG. 400.—*Puccinia graminis*: I. Transverse section of leaf of barberry with a spermogonium *s*, and two ascidia *a*; II. part of a 'rust-spot' from a grass-leaf with three uredospores *u*, and a teleutospore *t*; III. tuft of teleutospores *t* from a grass-leaf; *o* the ruptured epidermis ; IV. germinating teleutospore putting out a pro-mycelium, which bears two sporidia *sp*. (I. × about 30 ; II. about 300 ; III. 200 ; IV. 300). (After De Bary).

as a distinct genus under the name *Uredo.* The æcidia consist of round or oval receptacles, at the base of which is the *hymenium*, consisting of club-shaped basidia, each of which produces a series of æcidiospores. These are liberated by the bursting of the *peridium*, or layer of pseudo-parenchyma which immediately surrounds the æcidium ; and put out their germinating filaments through the stomata of the host-plant. On these are produced either uredospores, round or oval conidia, or teleutospores, which commence the cycle of generations afresh. In the Uredineæ this alternation of generations is connected with a change of the 'host' on or in which they live. Thus, the resting-spores of *Puccinia* hibernate on the haulms of grasses ; while the germinating filaments developed by the sporidia which are produced from them in the spring never germinate on grass, but penetrate into the epidermal cells of the leaves of the barberry, and rapidly develope there into the Fungus previously known as *Æcidium Berberidis.* The spores of this form again, when they enter the stomata in the leaves of suitable grasses, produce in them, and in them only, the mycelium of the *Puccinia*, which bears uredospores and resting-spores.

The USTILAGINEÆ resemble the Uredineæ in the general facts of their life-history. They are parasites very destructive in their operation, especially to grasses. Many of the well-known diseases of cereal crops, such as 'smut,' are due to their attacks. (See also p. 226.)

The BASIDIOMYCETES include the largest and best-known Fungi. The *hymenium* or reproductive portion consists of several layers of cells, in which some individual cells, much larger than the rest, are known as *basidia.* From these are abstricted the *basidiospores*, always produced in fours from the apex of the basidia. These reproduce the fungus directly, and no sexual mode of reproduction is known. The *mycelium* is composed of septated hyphæ ; this puts up the large massive *fructification* which bears the hymenia, often consisting of closely packed and interwoven hyphæ, constituting a *pseudo-parenchyma.* The hymenium may be either exposed on the surface of the fructification, when it is *gymnocarpous*, or it lines internal cavities, when it is *angiocarpous.*

A familiar example of the Hymenomycetes is furnished by the common mushroom, *Agaricus campestris*, belonging to the family Agaricini of the order Hymenomycetes. The basidiospores are here formed only on delicate plates or *lamellæ* on the under side of the *pileus* or cap-shaped fructification, which is elevated on a stalk or *stipes.* In many fungi this fructification is naked ; in others the lower side of the pileus is covered with a membrane which is ruptured when near maturity (Fig. 401) (*velum partiale* or *annulus*) ; or often the pileus and stalk are both enveloped in such a membrane (*velum universale*), or occasionally both are present (Fig. 402 I.). Among the basidia are frequently

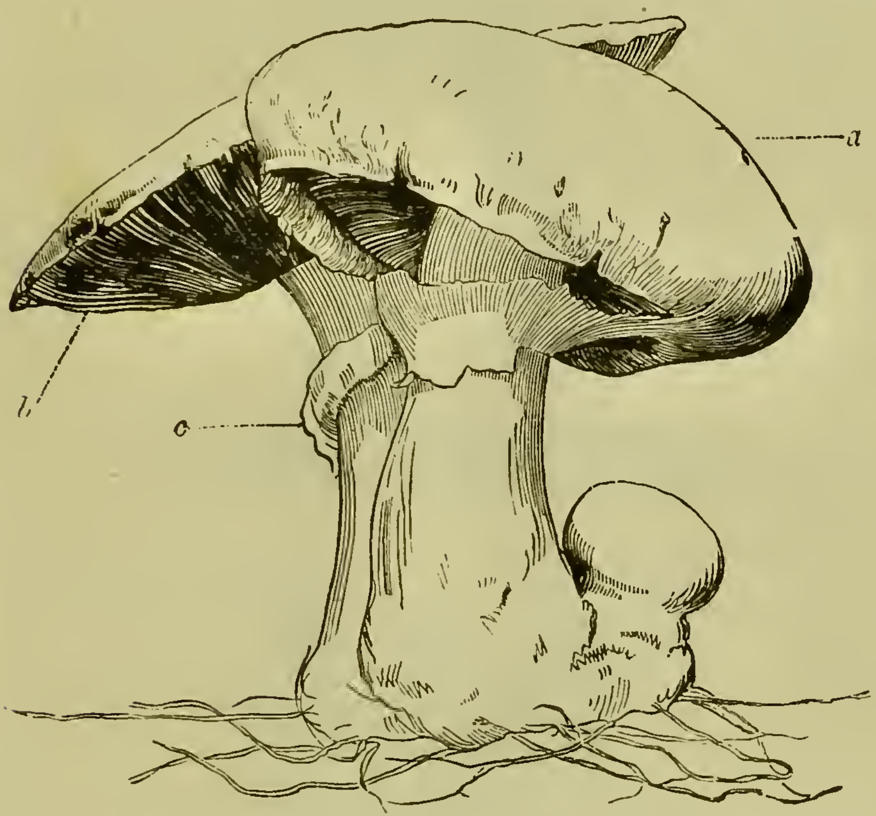


FIG. 401.—Mushroom, *Agaricus campestris* : one young globular and two mature fructifications, *a* pileus ; *b* lamellæ ; *c* annulus (natural size).

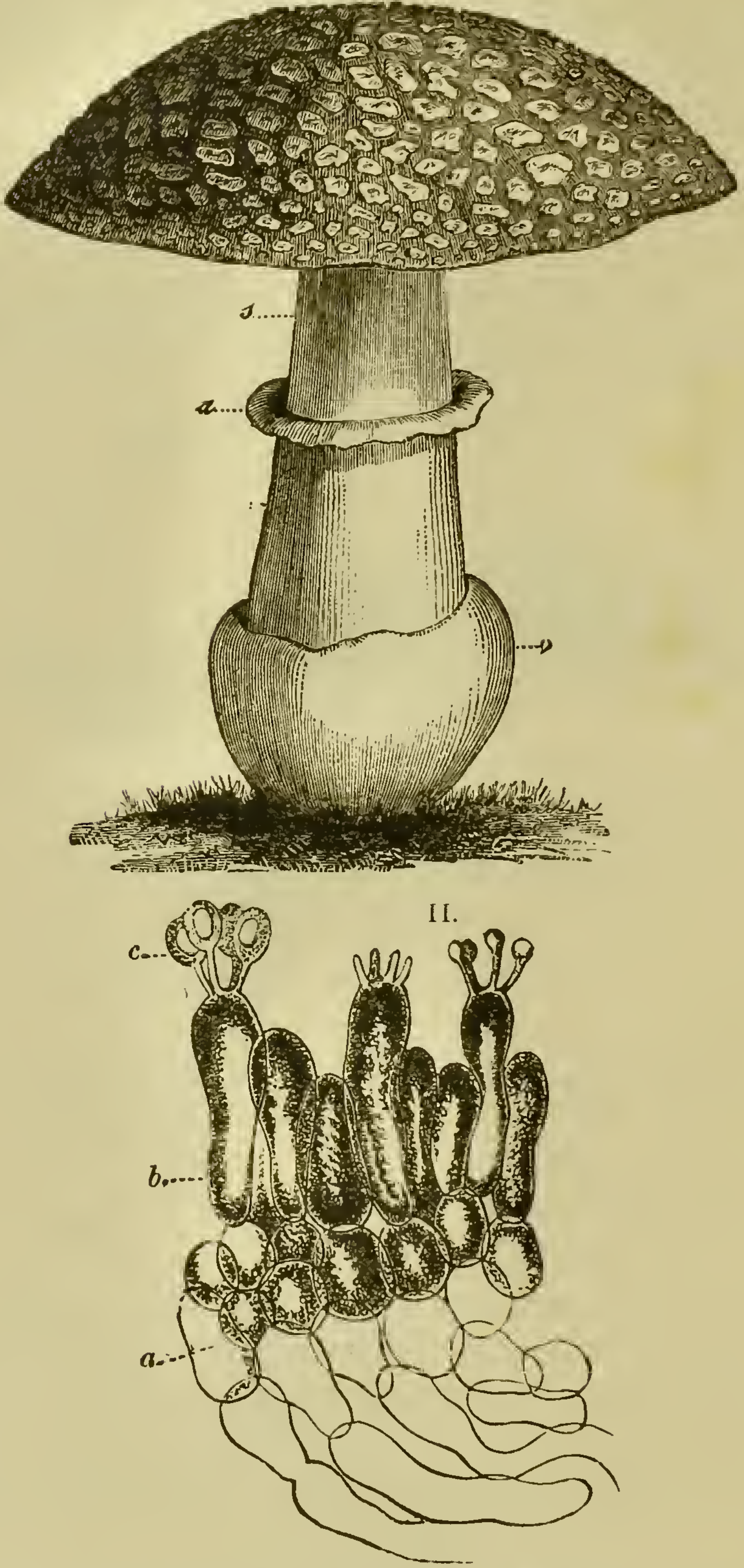


Fig. 402.—I. *Agaricus rubescens*: the fructification (natural size); *s* stipes; *v velum universale, a velum partiale* or annulus. II. Part of a longitudinal section through the hymenium of another species; *a* pseudo-parenchyma; *b* hymenium; *c* basidiospores. (× 400.)

to be found other greatly enlarged cells, the *cystidia*, the function of which is unknown, but which are possibly barren basidia. In another order, the Gasteromycetes, including *Phallus* and *Clathrus*, the hymenium, to which the term *gleba* is also given in these cases, is distributed into chambers, and is enclosed in an outer layer of pseudo-parenchyma, the *peridium*.

It is believed by many that the fructification of the Basidiomycetes is the product of a still undetected process of impregnation between sexual organs occurring on the mycelium.

The form of the hymenium differs in different families of the Hymenomycetes. In the Agaricini it is spread over the surface of lamellæ on the under side of the pileus; in the Polyporei (*Polyporus*, *Boletus*, &c.) it is spread over the cavity of tubes or pores; in the Hydnaceæ over teeth or spines. The Tremellini are distinguished by their jelly-like substance.

Several of the Hymenomycetes display the phenomenon of *phosphorescence*, due to slow decay and oxidation, either in their mycelium or fructification. The peculiar structures known as 'rhizomorphs,' common in damp cellars, are the long flocculent persistent mycelium of several species of *Agaricus*.

A number of the Hymenomycetes, as *Agaricus campestris* the common mushroom, *A. cæsareus*, *A. procerus* the 'parasol-mushroom,' *A. prunulus* the 'plum-mushroom,' *A. deliciosus*, *Boletus edulis*, *Cantharellus cibarius* the 'edible chantarelle,' &c., are edible; while others, as *Agaricus muscarius* the 'fly amanita,' *A. emeticus*, &c., are poisonous. *Merulius lacrymans* is the dry-rot so destructive to timber. Among officinal species are *Boletus laricis* and *Polyporus fomentarius*, which yields the 'amadou' of commerce. Among the more common *Gasteromycetes* are *Lycoperdon bovista* the 'puff-ball,' and *Phallus impudicus* the 'stink-horn.'

The Ascomycetes are a very numerous class of fungi, growing usually either on dead or decaying vegetable matter, and distinguished by the formation of *ascospores*, by free cell-formation, within special sacs or *asci*. Other non-sexual reproductive cells are *conidia*, produced in the

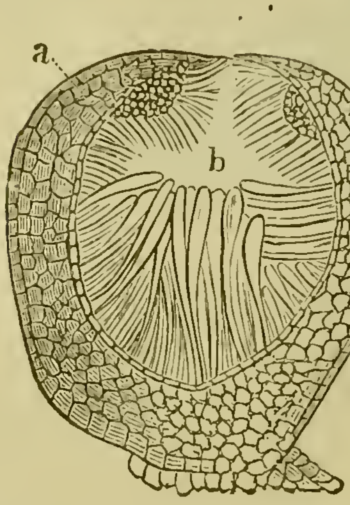


Fig. 403. — *Nectria inaurata* (Sphæriaceæ): *a* mature perithecium; *b* asci (× about 150).

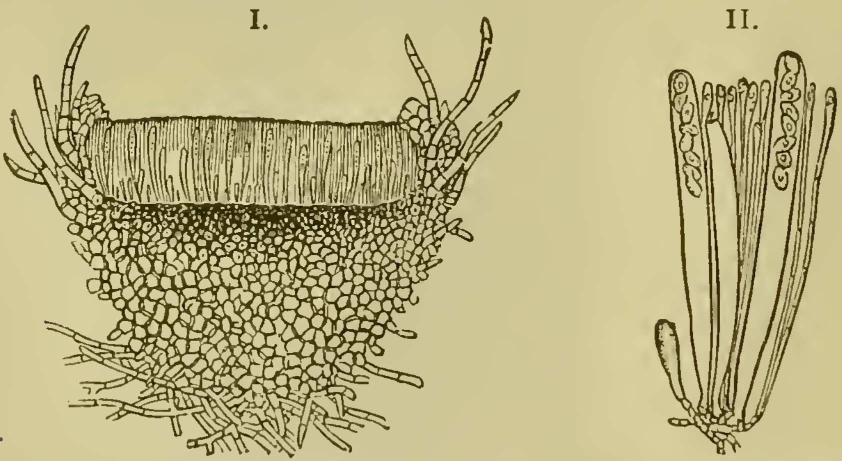


Fig. 404.—I. Transverse section through the fructification of *Ascobolus pulcherrimus* (magnified): II. a part of a fructification consisting of asci containing ascospores in various stages of development, and paraphyses (more strongly magnified).

ordinary way on *conidiophores*, and sometimes supported on basal cells known as *sterigmata*; and *stylospores*, produced internally in special receptacles, the *pycnidia.* Bodies known as *spermatia* are also found, within *spermogonia*, which are believed to be male sexual cells that have lost their function; they appear to have no power of germination. The asci are often enclosed in a special layer of pseudo-parenchyma, the *perithecium* (Fig. 403); and the asci are not unfrequently accompanied by barren filaments, the *paraphyses.* If the fructification or collection of asci is completely open, it is known as an *apothecium.* In a large number of the Ascomycetes no sexual organs have at present been detected, as is the case universally with the Hymenomycetes; in others, as in the Discomycetes, (Figs. 403, 404), the fructification is the result of the fertilisation of a *carpogonium* by a *pollinodium.* Each of these organs consists of a series of short crooked cells arising on neighbouring branches of the mycelium. Fecundation is effected by the pollinodium coiling itself round the carpogonium, and passing into it the protoplasmic contents of its cells. One of the cells of the carpogonium then developes into the 'ascogonium' or 'scolecite'; this puts out numerous hyphæ, on which are borne the asci. The ascospores being always produced by repeated bipartition (free cell-formation) of the contents of the ascus, their number is always some power of 2, the most usual being 8. The ascospores have always a double coat: an *exospore*, cuticularised and often warty, and an *endospore* of pure cellulose. On germination they produce a mycelium. Many of the Ascomycetes produce *sclerotia*, dense masses of hyphæ, enveloped in an indurated 'rind' or 'cortex.' They are the resting condition of the fungus, and develop a mycelium on germination.

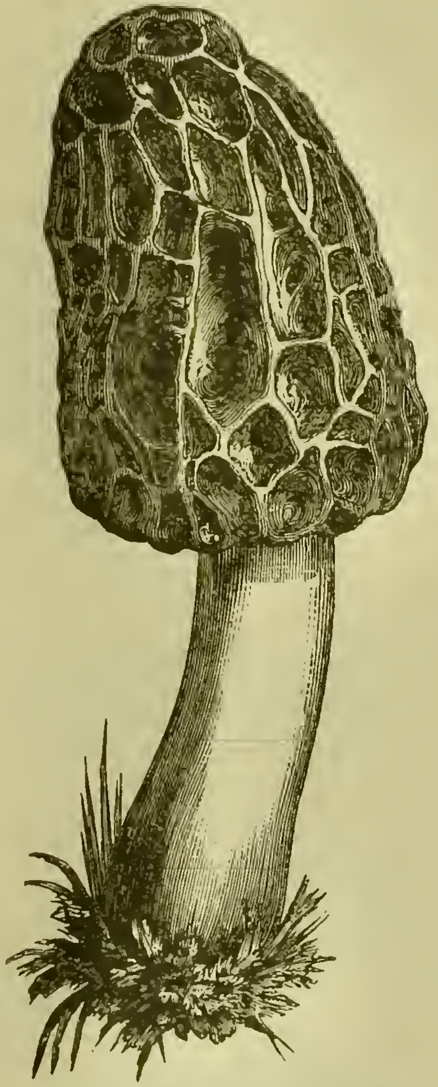


FIG. 405.—The morel, *Morchella esculenta* (natural size).

Some of the Discomycetes are large conspicuous fungi, as for example the edible morel (Fig. 405), others, like the various species of *Peziza*, are smaller, often very beautiful objects, growing on garden paths, dead leaves, &c. The disease known as 'muscardine,' which attacks the larva of the silkworm moth, is the 'botrytis' form of a Peziza (formerly called *Botrytis bassiana*), producing conidia as its only reproductive organs. The sclerotia of other species are exceedingly destructive to clover and other crops. To another order of the Ascomycetes, the Tuberaceæ, belongs the edible truffle, *Tuber æstivum* (Fig. 406), the edible portion or fructification being produced only underground.

Many of the commonest kinds of mould, such as the ordinary blue mould of cheese, &c., are fungi belonging to the genera *Penicillium* and *Aspergillus*, lowly developed forms of the Ascomycetes.

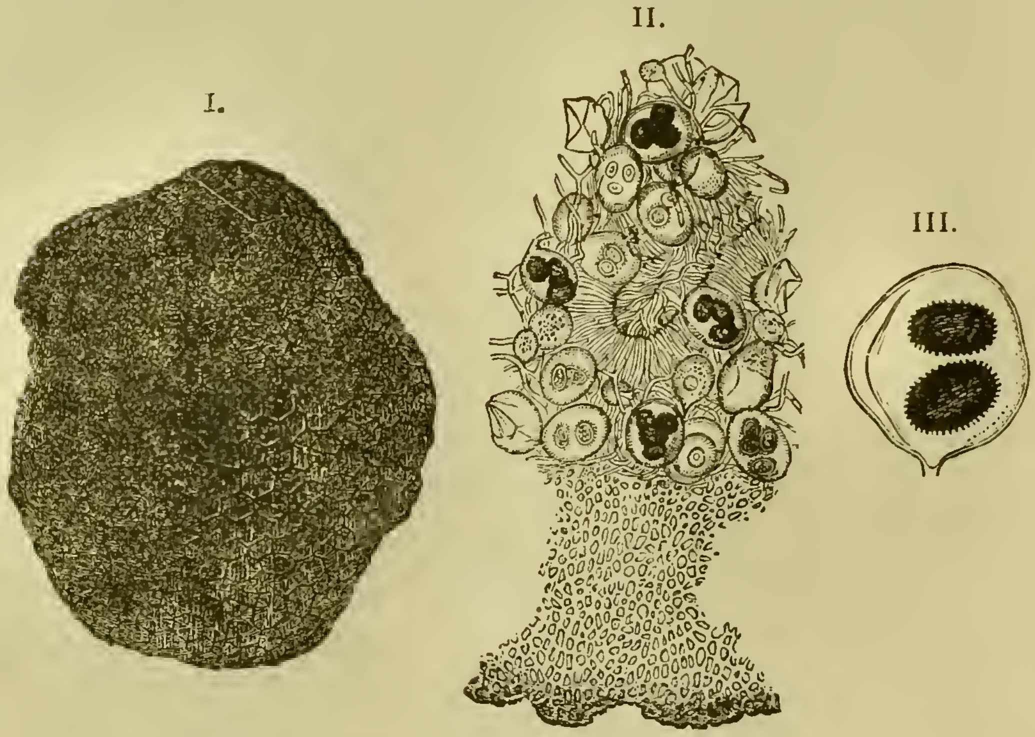


FIG. 406—Truffle, *Tuber melanosporum*: I. fructification (the part that is eaten); II. a part of the fructification with ascospores in different stages of maturity, the outer cortical layer or perithecium below (strongly magnified); III. ascus with two spores (more strongly magnified).

In *Penicillium*, one of the commonest forms of these moulds (see Fig. 1, p. 7), both the concealed part or *mycelium*, and that portion which is exposed to the atmosphere, the *aërial hyphæ*, consist of cells which agree in every essential point (except the absence of a nucleus) with the typical cell, varying only in size and form. The only reproductive bodies seen here are *conidia*, that is, ordinary cells of a spherical form produced at the ends of the aërial hyphæ, and detached in succession. They are true *spores*. They have the same property as the *Saccharomyces* cells, of retaining their vitality for a long period when dried; and, from their extreme lightness, are in this form disseminated with the greatest facility through the air. On reaching a nutrient substratum they germinate. A bulging makes its appearance at one or more points of the cell-wall, and the cell rapidly lengthens in one or more directions, and becomes a radiating and branched, but still unicellular, hypha. Subsequently the protoplasm divides transversely, septa of cellulose are formed, and the hypha becomes multicellular. Some branches of the hyphæ extend downwards, forming the mycelium, while others direct themselves upwards, and constitute the aërial hyphæ, which break up into conidia. Under ordinary circumstances the conidia are the only reproductive organs of *Penicillium* and *Aspergillus* ; but, as with other Tuberaceæ, when in entire darkness, sexual fructifications are produced. Under these conditions the ascogonium, after it has begun to germinate, remains for a long time in a sclerotoid state. But when germination is induced by artificial means, the *ascophorous hyphæ* separate themselves from the sclerotium, and form asci, in each of which are eight ascospores. These germinate and produce a mycelium, which again bears conidia.

Another parasitic fungi, the *Claviceps purpurea*, the cause of 'ergot' of rye (see Fig. 375, p. 228), belongs to the Pyrenomycetes, another order of Ascomycetes ; the medicinal ergot being a sclerotium formed in the ovary of the grass (see also p. 227). *Erysiphe Tuckeri* (Fig. 376, p. 229), formerly known as 'oidium,' is the cause of the well-known vine-mildew (see also p. 228).

LICHENS (Figs. 407–417) should properly be regarded, not as a separate section of the Ascomycetes, or even of Fungi, but as a peculiar condition of growth of many fungi, chiefly belonging to the Ascomycetes. They usually consist, when mature, of a well-developed layer of tissue, the *thallus*, composed, like that of Fungi, of interwoven hyphæ, which form a fibrous pseudo-parenchyma. Imbedded in this thallus are round or oval cells of a green or blue-green colour, the *gonidia*. Three types of structure of the thallus may generally be distinguished : the Stratified, the Pictorial, and the Gelatinous. If the gonidia are irregularly distributed throughout the thallus, it is said to be *homoiomerous* ; if they are arranged in definite layers, it is *heteromerous*.

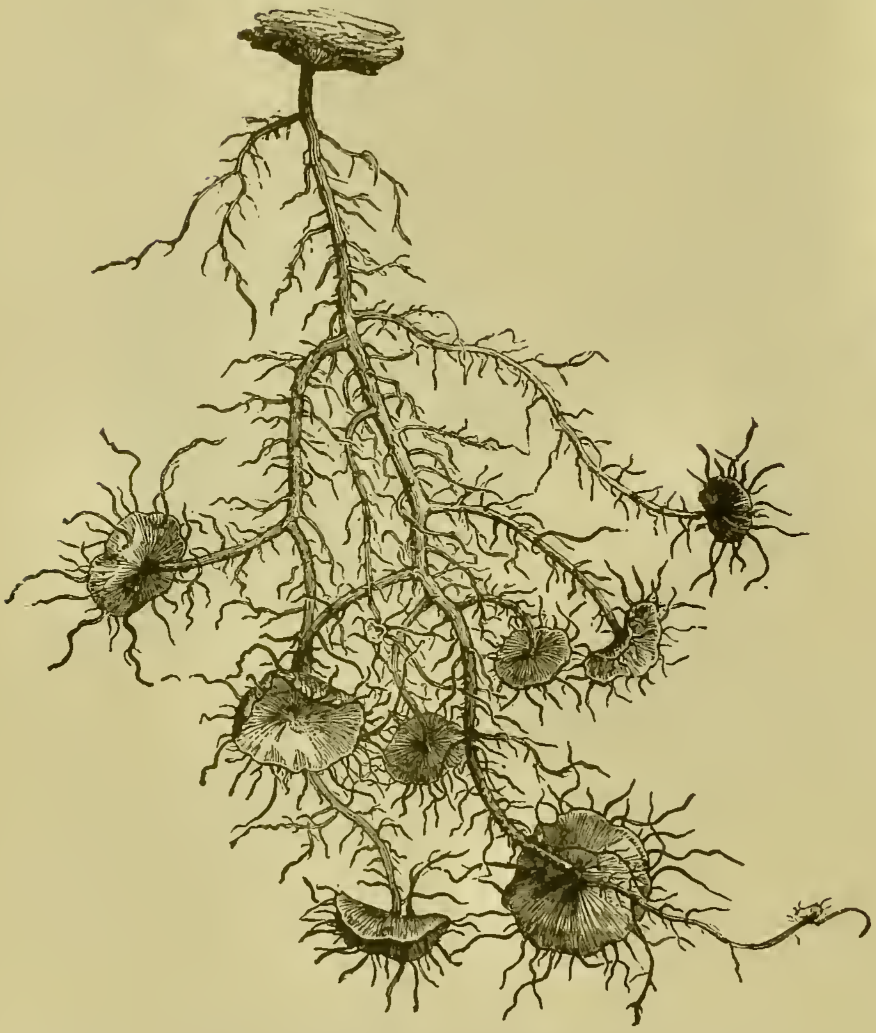


FIG. 407.—*Usnea barbata* : natural size, with the spoon-shaped apothecia.

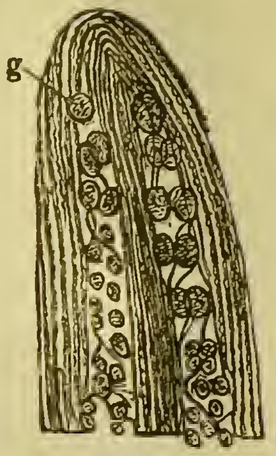


FIG. 408.--Longitudinal section through the middle of the apex of the thallus; the cortex, the gonidial layer *g*, and the medulla are clearly distinguishable (×515).

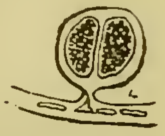


FIG. 409. — A single gonidium (×700).

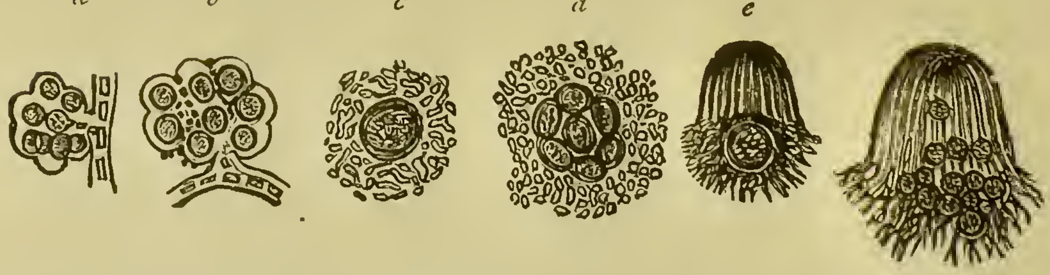


FIG. 410.—Development of the soredia : *a* gonidial group of eight cells ; *b* a similar group in a more advanced stage of development ; *c* longitudinal section of a mature soredium ; *d* the same with the gonidia more distinctly separated , *e* a germinating soredium ; *f* the same further developed (× 500–700).

Sections through the thallus of the *Stratified Lichens* (Fig. 408) almost always show two distinct layers of tissue, a comparatively thin, usually transparent but close outer layer or *cortex*, and an inner looser hyphal layer enclosed by the former, the *medulla*. The two layers are, however, formed of ramifications of the same hyphæ. At the line where they meet, the gonidia almost always constitute a zone of variable thickness, the *gonidial layer* (Fig. 408 *g*). In the *Fruticose Lichens* the cortex commonly constitutes a layer of uniform thickness all round; while in the *Foliaceous* forms it is usually different on the upper surface exposed to the light, and on the under surface. The thallus of the *Crustaceous Lichens* presents an affinity to the latter form in being fixed to the substratum by capillary or bristle-like *rhizines*, so that it cannot be removed without injury.

The *Pictorial Lichens* or Graphideæ form thin patch-like incrustations on stones and the bark of trees (Fig. 411).

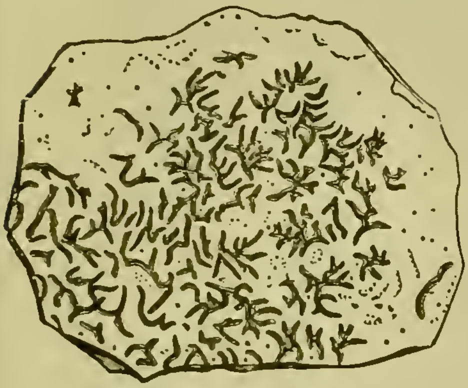


FIG. 411.—*Graphis elegans*, a Pictorial Lichen (natural size).

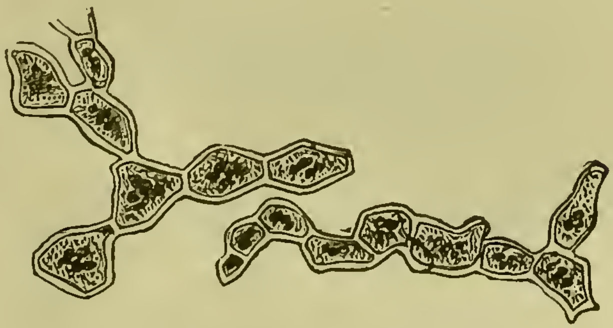


FIG. 412.—Chain of gonidia of a Pictorial Lichen, *Graphis scripta* (× 390).

The chief peculiarity of their thallus consists in the nature of their gonidia, which are often united into many-celled alga-like rows of cells (Fig. 412), increasing in length by division of the terminal cell.

The thallus of the *Gelatinous Lichens* (Fig. 413) has a leaf-like or an arborescent form, or consists of granules which constitute an incrustation. When dry it is cartilaginous or brittle, and then absorbs water eagerly, swelling up into a gelatinous body. Sections (Fig. 413 I.) show that it consists of gonidia and narrow filaments of cells imbedded in an apparently homogeneous jelly. The contents of the cells are always colourless and invisible, and apparently contain no organised constituents such as grains of starch. The cell-walls of many Lichens (as, *e.g.*, the so-called 'Iceland moss,' *Cetraria islandica*) swell up, when boiled in water, into a homogeneous jelly, forming the so-called 'moss or lichen-starch,' or *lichenin.*

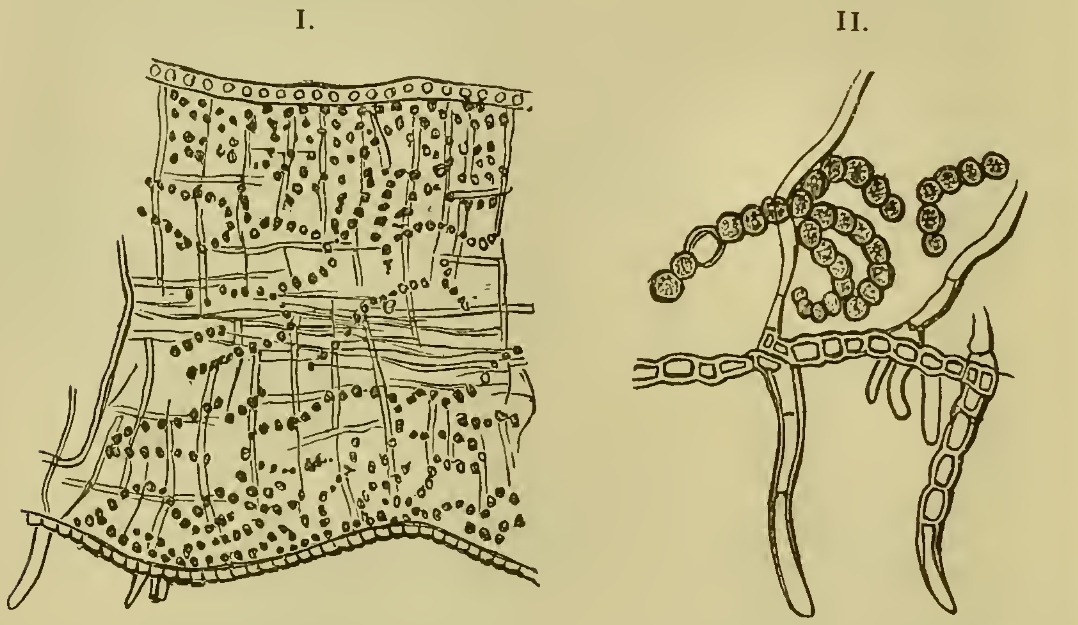


Fig. 413.—I. Longitudinal section through the thallus of a Gelatinous Lichen, *Mallotium Hildenbrandii* (× 190): II. piece of a very thin section through the under side with moniliform chains of gonidia (after De Bary, × 390).

Among the non-sexual organs of reproduction of Lichens are the *soredia* (Fig. 410), which are developed in the gonidial layer; groups of gonidia become enclosed in peculiar fibrous envelopes, and, when so completely inwoven, grow rapidly, and thus exercise a pressure on the cortex which ruptures it. The soredia which protrude through the crevices caused in this way increase in the same manner or develope into new individuals. In addition, Lichens are also provided with *stylospores* contained in *pycnidia.*

True sexual organs of reproduction occur in Lichens, namely a *carpogonium*, fertilised by *spermatia* contained in *spermogonia* ; but although these organs are general in all the groups, it is only in the Collemaceæ that the actual process of impregnation has been observed. The carpogonium consists of two parts, a straight *trichogyne*, and a coiled *ascogonium.* The point of the trichogonium protrudes through the surface of the thallus, in which the rest of the thallus is imbedded, the spermatia are carried to it by currents of water, and, passing through it to the ascogonium, fertilise the oosphere contained in the latter. From the ascogonium are then developed barren *paraphyses*, and *ascophorous hyphæ*, which bear the *asci.* The receptacle which contains the asci is either an open *apothecium* (Figs. 407, p. 286; 414), like that of the Discomycetes, when the lichen is said to be *gymnocarpous*, or a closed *perithecium*, like that of the Pyrenomycetes, when it is *angiocarpous.* The development of the apothecia always begins in the interior of the thallus. When mature they consist of the external tissue or *excipulum* ; of a layer in which larger and stouter hyphal filaments are developed than those found in the remainder of the tissue, the ascophorous hyphæ or subhymenial layer ; and of the true *hymenial layer*, composed of parallel hyphæ or paraphyses and of the asci. These latter usually contain eight ascospores formed simultaneously.

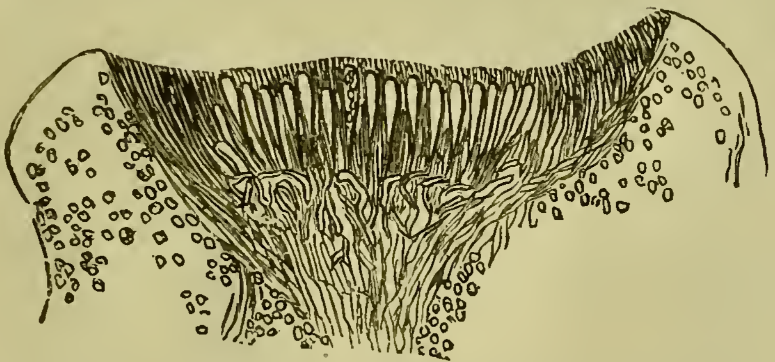


FIG. 414.—Vertical section through the middle of a young apothecium of *Lecanora subfusca* ; the club-shaped asci are developed at the apex of the ascophorous hyphæ, and lie imbedded in the hymenium ; the layers at each side contain spherical gonidia (× 10).

The compound nature of Lichens, due to a *symbiosis* of a Fungus and an Alga, may now be said to be completely established. The gonidia are groups of Algæ, or rather of chlorophyllaceous Protophyta, belonging either to the Palmellaceæ or the Nostocaceæ. The whole of the rest of the Lichen, including the sexual organs, belongs to a Fungus which carries on a kind of parasitic existence on the gonidia, and which belongs in the great majority of cases to the Ascomycetes, rarely to the Hymenomycetes. The gonidia can be detached from the thallus, and will then carry on an independent existence, resembling in all respects that of the green organisms named; and in a few instances, as that of *Collema glaucescens*, the perfect Lichen has been constructed synthetically, by causing the spores of the Fungus to germinate in contact with the Alga.

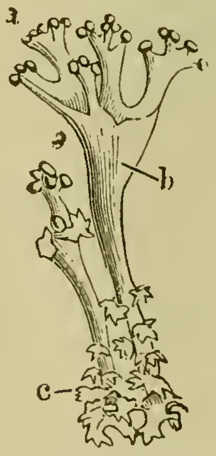


FIG. 415.—*Cladonia digitata*, a Fruticose Lichen : *a* apothecia ; *b* cup ; *c* foliaceous thallus (natural size).

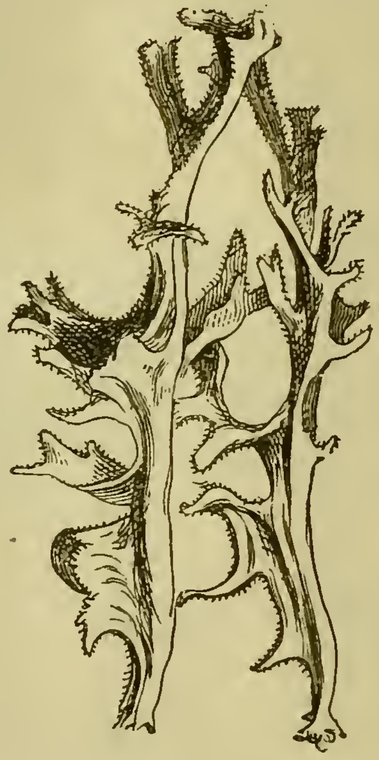


FIG. 416.—*Cetraria islandica*, a Fruticose Lichen ; the margin of the thallus is fringed, and bears spermogonia on the edge of the fringe ; there are no apothecia.

Lichens are classified as under, viz. :—

I. Lichens with a stratified thallus :—HETEROMEROUS LICHENS.
   1. FRUTICOSE Lichens ; thallus more or less arborescent in form (Figs. 407-410, p. 286 ; 415, 416).
   2. FOLIACEOUS Lichens : thallus leaf-like (Fig. 417).
   3. CRUSTACEOUS Lichens : thallus crustaceous.

II. Lichens with unstratified thallus:—HOMOIOMEROUS LICHENS.
   1. GELATINOUS Lichens: thallus gelatinous (Fig. 413, p. 288).
   2. PICTORIAL Lichens: thallus forming a very thin irregular incrustation (Figs. 411, 412, p. 287).

The gelatinous *lichenin*, characteristic of many Lichens, renders them useful as articles of food to northern nations and their domestic animals, or as medicinal products. Of this character are the so-called 'Iceland moss' *Cetraria islandica*, (Fig. 416), the 'rein-deer moss' *Cladonia rangiferina*, and *Sticta pulmonacea*. *Parmelia parietina* is also used as a febrifuge, from its containing a bitter principle, which is present also in other kinds. Several other Lichens, as *Roccella tinctoria*, *Lecanora tartarea*, *Variolaria dealbata*, *Gyrophora pustulata*, and *Lecanora atra* are also important articles of commerce, in consequence of a pigment which is blue or red according to the mode in which it has been prepared, and which is known as orchil, litmus, and cudbear.

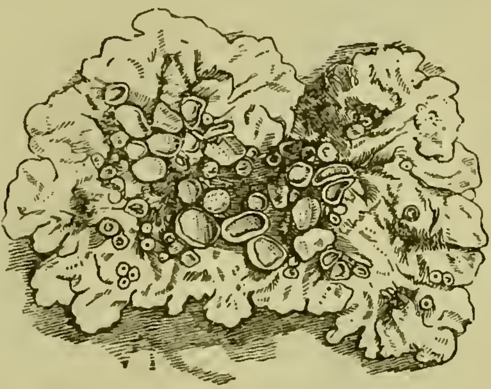


FIG. 417.—*Parmelia tiliacea* a Foliaceous Lichen, with apothecia.

Lichens are most abundant in the colder regions of the globe, and occur on the utmost limits of vegetation. From this circumstance, and from the ease with which they grow where the means of living are extremely scanty—some of them flourishing on bare hard rocks, and others even thriving on glass and iron—they are of considerable importance in the economy of Nature.

CHARALES.

CLASS IV. *Characeæ.*

The Characeæ present in their structure and development a transition from Algæ to Muscineæ; for, although very similar in habit to many Algæ, and therefore at one time included in that class, they are nevertheless really more nearly allied to Mosses, not only in their mode of germination, but because they are Acrogens in contradistinction to Thallogens. They grow in fresh water, and consist of cellular filaments, which are branched in a verticillate manner at regular intervals (Fig. 418 I.). There are only two genera, *Chara* and *Nitella*, known as 'Brittle-worts,' including a considerable number of species distributed over the whole globe. In *Nitella* each internode consists of only

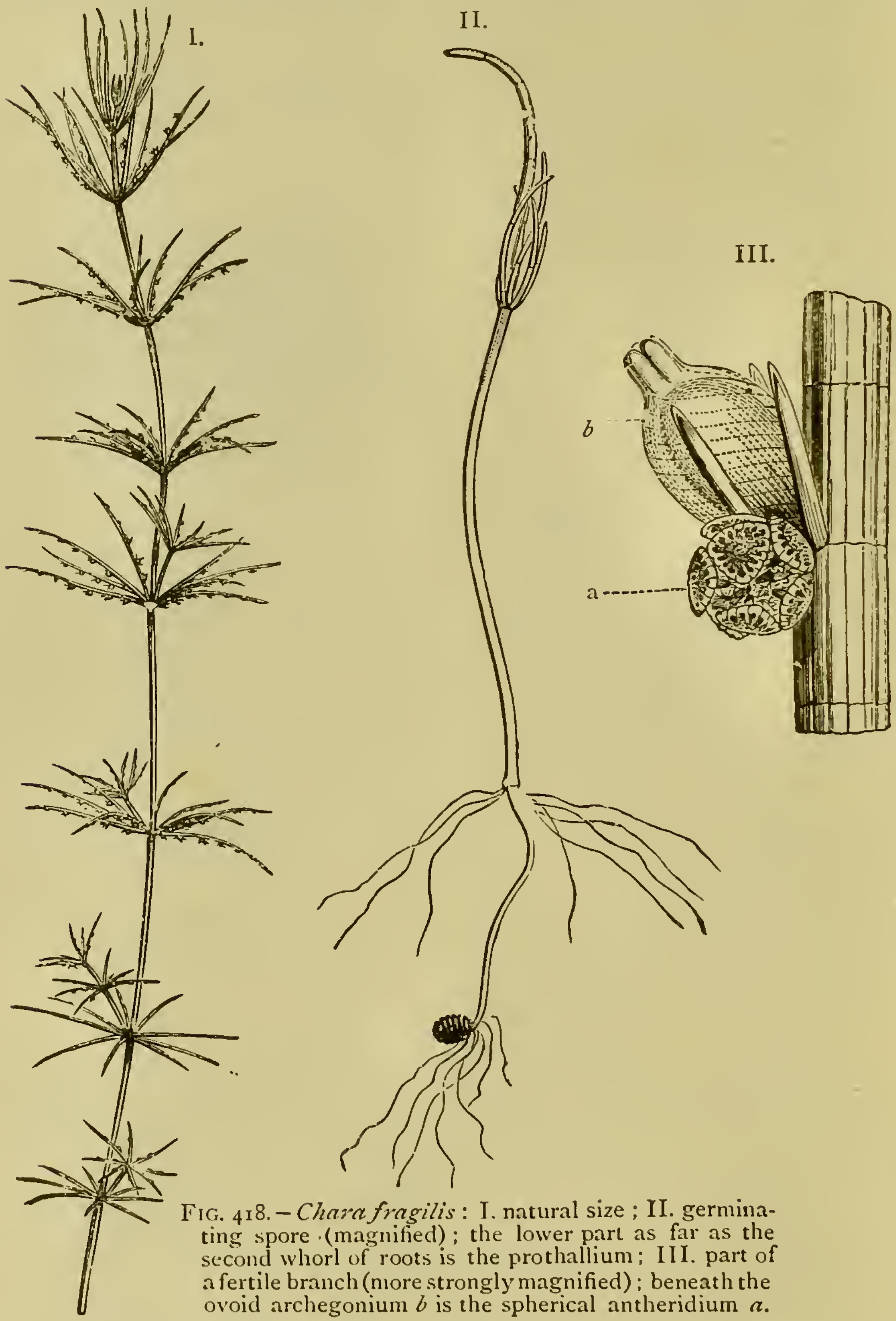


FIG. 418.—*Chara fragilis*: I. natural size; II. germinating spore (magnified); the lower part as far as the second whorl of roots is the prothallium; III. part of a fertile branch (more strongly magnified); beneath the ovoid archegonium *b* is the spherical antheridium *a*.

a single cell, while in the stem of *Chara* there is a central or axial cell, surrounded in a spiral manner by other cells, which form a cortex. Multiplication takes place partly by single cells becoming detached, partly by impregnation. In some species, as *Chara hispida* (Fig. 419) an antheridium or 'globule' and a female organ called the 'nucule' stand beneath a lateral branch; in other species the two organs, which may be recognised in an immature condition as small red knobs on the plant, are found on different individuals. The *antheridium* (Fig. 418 III., *a*) is a sessile globular body, and consists of eight cortical cells which open when ripe. In the interior are a number of cellular filaments (Fig. 420 I.), coiled round one another, from each separate cell of which is developed an antherozoid or spermatozoid (Fig. 420 II.). The *archegonium* (Fig. 418 III., *b*) consists of an axial row of cells which is closely surrounded by five tubes coiled spirally round it. The *oosperm* is developed, as the result of impregnation, from the large apical cell of the inner axial row,

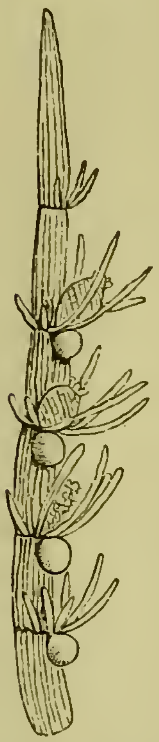


FIG. 419.—Fertile branch of *Chara hispida* (magnified).

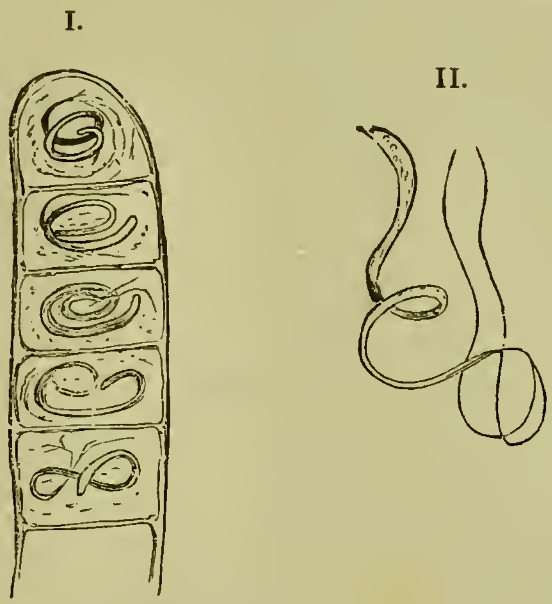


FIG. 420.—*Nitella syncarpa*: I. end of a cellular filament from an antheridium, with antherozoids in the interior of the cells; II. a free antherozoid (× 500).

the oosphere. In the autumn, when the annual plant dies down, the oosperm falls to the bottom of the water, the young plant developing from it in the spring. The first algoid cells of the young plant are considered a *prothallium*, on which the plant itself grows as a lateral branch (Fig. 418 II.). The process of impregnation itself takes place in this manner. At the moment of maturity the neck of the five peripheral tubes of the archegonium becomes loosened, and between the five clefts thus formed antherozoids penetrate into the oosphere. The Characeæ have no economical or medicinal value, but are of importance in respect to our knowledge of the life of plants.

[Several species of *Chara* are common in freshwater ditches, ponds, and streams, forming tangled masses, easily distinguished from Algæ by the verticillate arrangement of the branches, and by the gritty nature of the whole plant caused by the deposition of calcareous matter ; when decaying the plant emits an offensive smell, resembling that of sulphuretted hydrogen. *Nitella* is not so abundant, and is destitute of the calcareous incrustation. The plant is, in each case, fixed in the soil by slender root-filaments or *rhizoids*.

The central or axial cell of each internode in *Chara* is very large compared with the size of the cells which surround it, and which form the *cortical layer*. Each node consists of a transverse plate of small cells resembling those of the cortical layer, and separating the internodal cells from one another. The branches and secondary branches (sometimes called leaves) resemble the stem in structure, the latter always ending in a much-elongated pointed cell. The apex of the stem forms a compact terminal bud, beneath which the internodes become gradually longer as you approach the base of the stem. Growth, *i.e.* the formation of new nodes and internodes, takes place immediately beneath this terminal bud, new rhizoids being first formed, and then branches bearing in their axils the reproductive organs, which are easily made out as minute orange-red bodies. A vegetative mode of reproduction sometimes takes place by means of *bulbils*, which become detached. The growing point, which occupies the centre of the terminal bud, consists of two cells lying one above another; while beneath the lower of these is another cell which divides longitudinally, and developes into the cellular transverse partition or node. Below this again is a single elongated internodal cell, and beneath this again a rudimentary node, and so on. The internodal cells increase in size, but never divide. The leaves or lateral branches, on the other hand, are developed from outgrowths of some of the peripheral cells of the node. The cortical layer which surrounds each internode is developed, not from the internodal cell, but by continual growth and division of the peripheral nodal cells, which from the first overlap the internode, and gradually assume a spiral arrangement. The cells of *Chara* always contain a nucleus, and afford a remarkably good illustration of the phenomena of *rotation* (see p. 10). This movement is exhibited especially in the inner layer of protoplasm next the central vacuole, the nucleus being carried round in the stream ; while the outermost layer which includes the chlorophyll-grains is quite motionless.

The eight cortical cells of which the wall of the antheridium or 'globule' consists, are sometimes called *shields* ; the four nearer the base are four-sided, the four nearer the apex three-sided. From the middle of the inner face of each shield a cylindrical cell, termed a *manubrium*, projects inwards, nearly to the centre of the antheridium ; and at the extremity of each manubrium is a roundish hyaline cell, the *head* or *capitulum*. The shields, manubria, and capitula form therefore together twenty-four cells, which, together with the pedicel-cell of the antheridium, constitute its framework. Each capitulum bears six smaller cells, *secondary heads* or *capitula* ; and from each of these grow four long whip-shaped filaments, the number of which therefore is about 200. Each of these 200 filaments divides transversely into from 100 to 200 cells, and in each of these cells an antherozoid is produced (Fig. 420, I. II.), provided with two cilia, by means of which it moves rapidly about when it escapes, by the separation of the shields and rupture of the parent-cell. The number of antherozoids produced by a single antheridium may therefore be from 20,000 to 40,000.

The Characeæ do not exhibit any true alternation of generations; the fertilised oosphere germinating directly in the soil, without the intervention of a non-sexual generation. The young plant is developed from the growth of a single cell of the prothallium, situated at some distance below its free extremity; this cell gives rise to a set of leaves, among which a bud appears which grows into a new *Chara.*—Ed.]

MUSCINEÆ.

Class V. *Hepaticæ.*

The Hepaticæ or Liverworts are elegant delicate plants, usually of a bright green colour, which form a beautiful transition from the Thallogens to the Acrogens. Many of them, as *Anthoceros* (Fig. 421), are true Thallogens, having no leaves, and are included in the class only on account of their mode of reproduction. Some bear a great external resemblance to certain Lichens; and in others the true leaves are only represented by scales. These forms, the *Thalloid* or Frondose *Hepaticæ* (Fig. 422), are contrasted with the *Foliose* forms; but even in these latter the leaves never have so much as a mid-rib, even when the stem contains vascular bundles of low organisation in the form of cambium-strings. Often, especially in *Jungermannia* (Fig. 423), the leaves stand in two rows, running in right- or left-handed spirals. In some genera with stems creeping on the earth or on the bark of trees, besides these larger

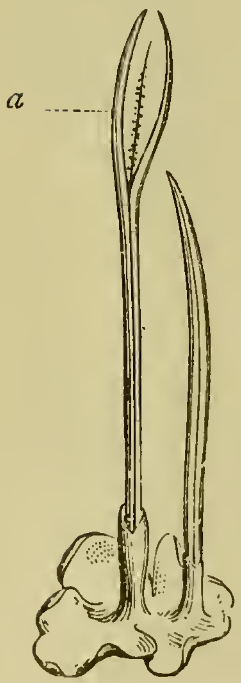


Fig. 421.—*Anthoceros lævis*: *a* a burst sporogonium.

leaves, which are all on the upper side, there is a third row of smaller leaves (Figs. 424 II., 425), the *amphigastria*, adpressed to the under side of the stem. The Hepaticæ never have true roots; *rhizoids* replace them both in position and in function.

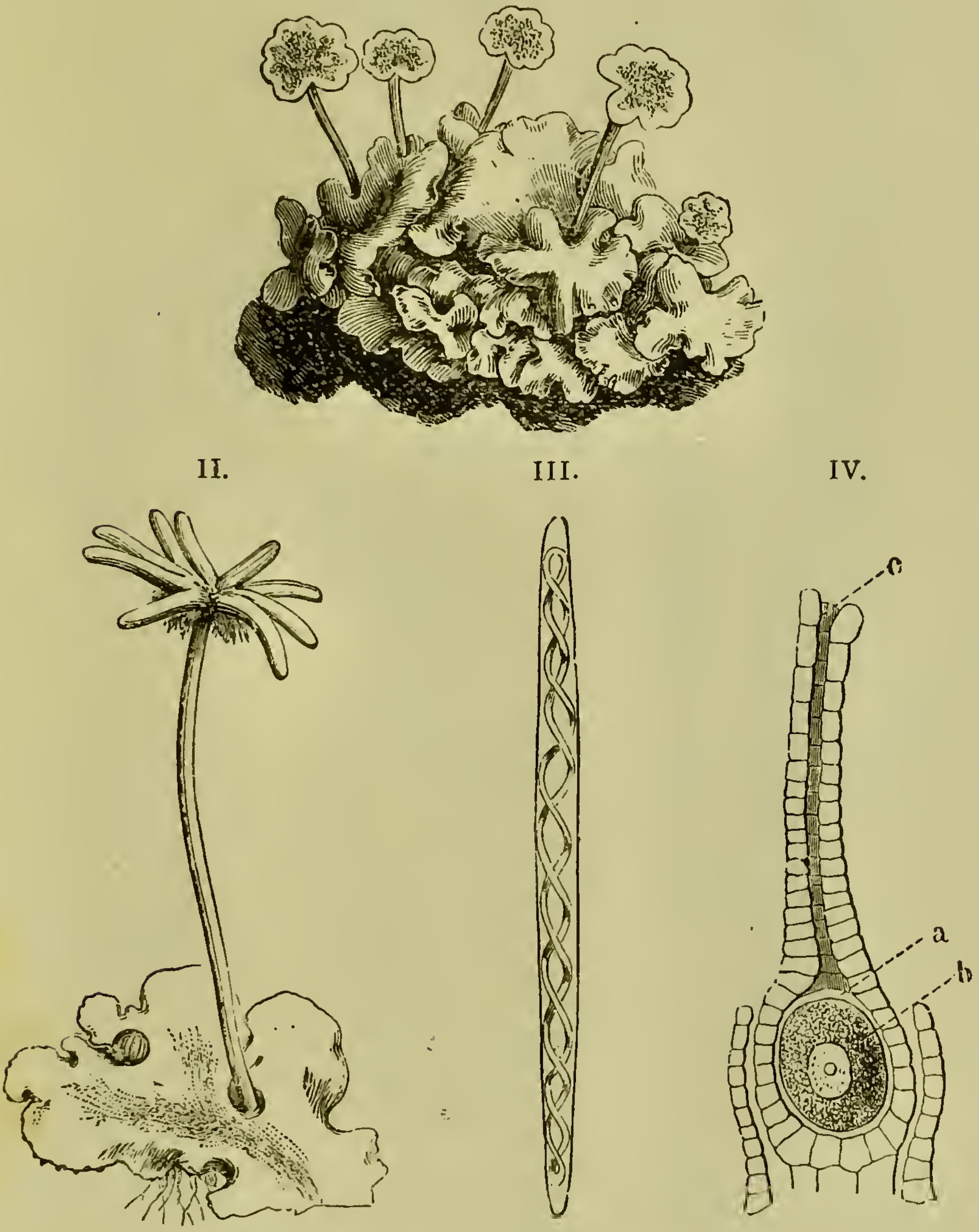


FIG. 422.—*Marchantia polymorpha*; I. thallus with five antheridial receptacles (natural size); II. thallus with an archegonial receptacle (natural size); III. elater-cell with a continuous doubly spiral thread or elater (× 200); IV. archegonium; *a* central cell, *b* oosphere with nucleus, *c* neck (× 200).

The internal structure of the stem is extremely simple. In the Foliose Hepaticæ it consists of an elongated parenchyma more strongly thickened externally, and thus forming a cortical layer passing over gradually into the central tissue. The Thalloid Hepaticæ, on the contrary, have a well-

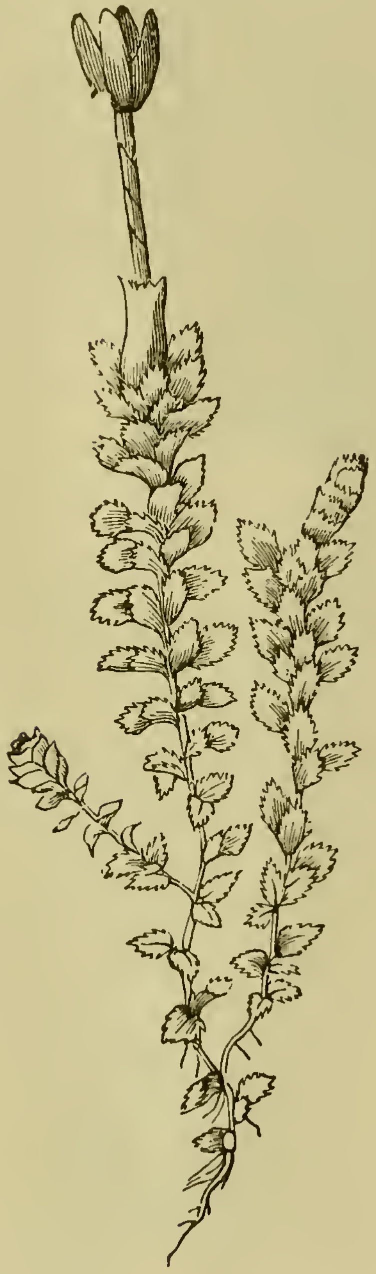


FIG. 423.—*Jungermannia nemorosa* (× 10).

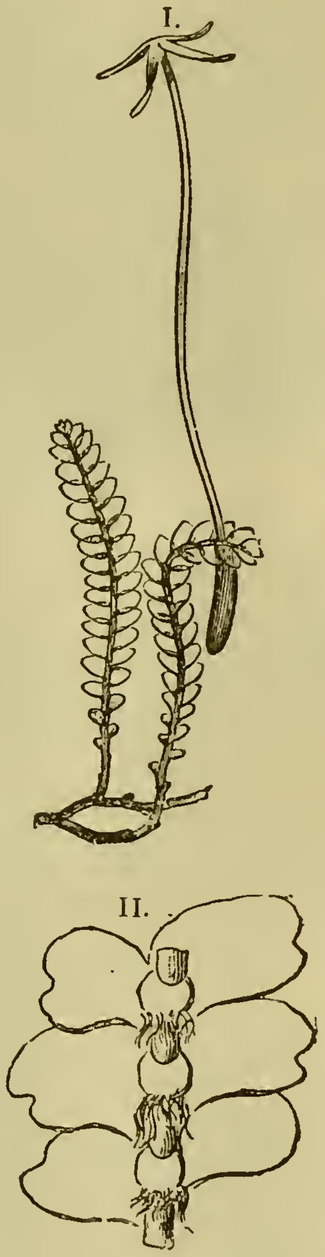


FIG. 424.—I. *Calypogeia Trichomanis*; II. under side of the stem with amphigastria (magnified).

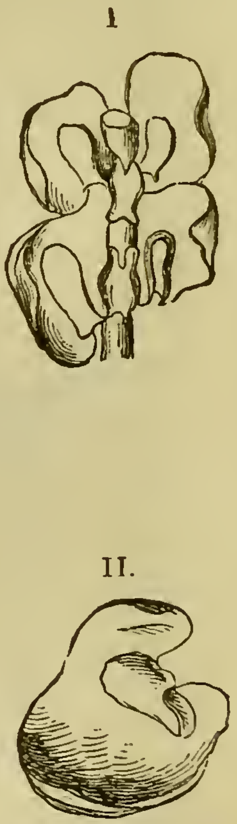


FIG. 425.—I. Under side of the stem of *Frullania Tamarisci* with the amphigastria and true leaves (magnified); II. leaf of *Frullania dilatata* (magnified).

marked epidermis, in which are a few scattered stomata, and which puts out rhizoids from its under side. In the most highly developed order, the Marchantieæ, we find the first rudiments of vascular bundles, in the form of elongated cells containing little or no chlorophyll but often crystals. The leaves consist of a single layer of uniform tabular cells.

There are two modes of reproduction: by fertilised oospheres, and by asexual buds or *gemmæ*. The latter are groups of cells which become detached from the plant, and, under favourable circumstances, develope into new individuals. In the Thalloid Hepaticæ they are usually found at the bottom of saucer- or spoon-shaped organs, the *cupules* (Fig. 349, p. 179); in other families they arise on the margin of the leaves or at the apex of the stem.

The sexual organs arise on the stem of the mature plant; some species being monœcious, and others diœcious. The male organ, or *antheridium*, is a stalked, usually spherical body, consisting of a cellular envelope or coat, and an internal portion formed of delicate cells. These last escape when the organ is mature, a spermatozoid or antherozoid having previously been developed in each cell, consisting of a spirally coiled thread furnished at the end with two long vibratile hairs or cilia. The female organ, or *archegonium* (Fig. 422 IV.) is a flask-shaped organ, enclosing near its base a large *central cell.* A canal leading to the central cell is formed in the neck of the archegonium by the disappearance of the septa of the axial bundle of cells, the *canal-cells*; the canal appears to be at first closed outwardly, but opens at the period of maturity by the separation of the apical cells, and thus gives access to the antherozoids. Before the antherozoids reach the central cell, the *oosphere* has been formed in the latter by free cell-formation, and gradually increases to such a size as completely to fill up the central cell, the *sporogonium* being developed from it after impregnation. The rudiment of this organ is first of all surrounded by a cell-wall, and then gradually developes—under the shelter of the archegonium, which grows with it and which is from this time called the *calyptra*—and developes into the stalked sporogonium. The sporogonium does not anywhere unite in its growth with the vegetative structure, even when its pedicel penetrates into its tissue. When mature, the sporogonium, elevated by the sudden and rapid increase in length of the pedicel or *seta*, ruptures the calyptra, opens, and allows the escape of a great number of spores. As a rule, several archegonia are grouped together into a female or *archegonial receptacle*, and several antheridia into a male or *antheridial receptacle*. The archegonium is sometimes surrounded by a so-called 'calyx' [or *perichætium*], consisting of several connate leaves. In the sporogonia of the Hepaticæ there usually occur, in addition to the spores, also peculiar elongated cells termed *elaters*, furnished with a brown spiral band, which is sometimes simple, as in *Frullania*, sometimes double (Fig. 422 III.). Rarely, as in *Anthoceros*, a row of cells or *columella* remains in addition in the axis of the sporogonium (Fig. 421). The sporogonium usually opens with four, in *Anthoceros* with two valves; in the Riccieæ it bursts irregularly. On germination the spore first puts out an irregular, often filiform, structure, the *prothallium*, on which the bud is produced from which the young plant arises. The course of development of the Hepaticæ shows a clearly marked alternation of generations. The first (sexual) generation begins with the germinating spore, and closes with the act of fertilisation; the second (asexual) generation consists of the sporogonium.

The Hepaticæ are classified into four families:—

1. RICCIEÆ. The thallus is expanded flat and floats on water; the antheridia and archegonia are imbedded in the thallus, and do not project above it; the sporogonium dehisces irregularly, and contains no elaters.

2. ANTHOCEROTEÆ. The thallus is expanded flat; the pod-like

stalked sporogonium has a columella; [the elaters have no spiral bands] (Fig. 421, p. 296).

3. MARCHANTIEÆ. The flat coriaceous thallus is branched dichotomously [and possesses a mid-rib; it is characterised by stomata of remarkable complexity]. The sporogonia are collected on a stalked organ or archegonial receptacle, and burst into four valves; [they contain elaters] (Fig. 422, p. 297).

4. JUNGERMANNIEÆ. [The vegetative structure is usually differentiated into a stem and distinct leaves]; the sporogonium bursts into four valves [and contains elaters] (Fig. 423, p. 298).

The Hepaticæ are distributed throughout the world, but are of no economical importance.

CLASS VI. *Musci.*

The Musci or Mosses are nearly related to the Hepaticæ; but are in general of a higher type, no longer possessing any of the characteristic features of Thallogens, but having a cylindrical stem covered with leaves (Figs. 427, 434). The stem of the order known as Sphagnaceæ is divided by narrow elongated cells, which are often lignified, into a central large-celled axial and a looser cortical portion consisting of only a few cells (Fig. 426 I.). True vascular bundles are altogether wanting, but in most other families of Mosses there is in the centre of the stem an axis of simple structure, which does not contain true vessels, but which is often described as a vascular bundle (Fig. 426 II.). This often consists only of a few thick- or thin-walled cells, not sharply distinguished from the parenchyma of the stem, which serve for the conduction of the sap, and therefore perform the function of a vascular bundle. In some Mosses there are, however, cells with thicker walls, on which may be seen a very delicate spiral striation, and which therefore, altogether call to mind a vascular bundle. These are sometimes central; but sometimes, as in *Polytrichum*, give place to a central medulla. Lateral branches from these bundles sometimes pass into the leaves as veins. The leaves are often narrow, of very thin or even membranous texture, and

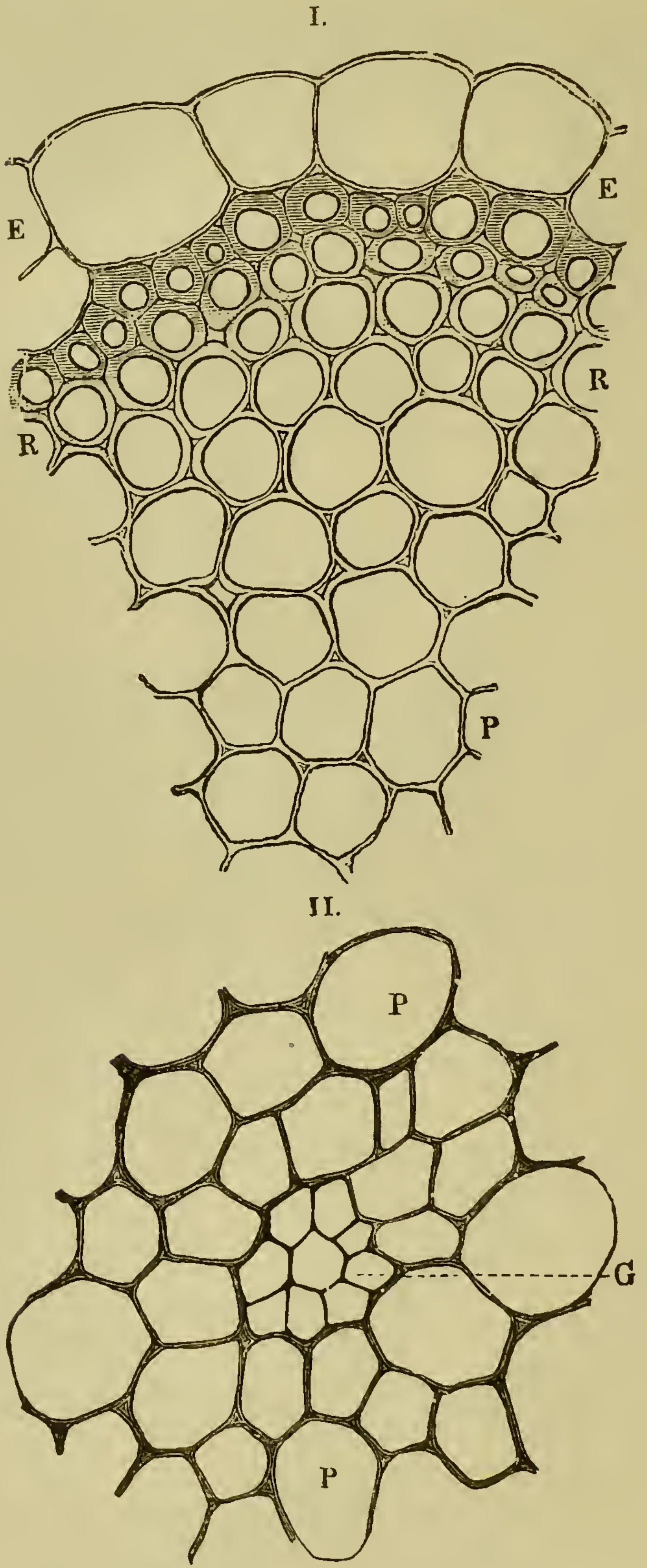


Fig. 426.—I. Part of a transverse section through the stem of *Sphagnum cymbifolium*; E epidermal cells; R thickened and coloured cortical cells; P parenchyma of the stem (× 320); II. central portion of a transverse section through the stem of *Climacium dendroides*: G central axis; P brown parenchyma of the stem (× 400).

of simple structure. They usually consist, with the exception of the veins, of only a single layer of parenchymatous cells; but exceptions occur in the case of *Sphagnum* and other Mosses. In *Polytrichum* the surface also has cells pro-

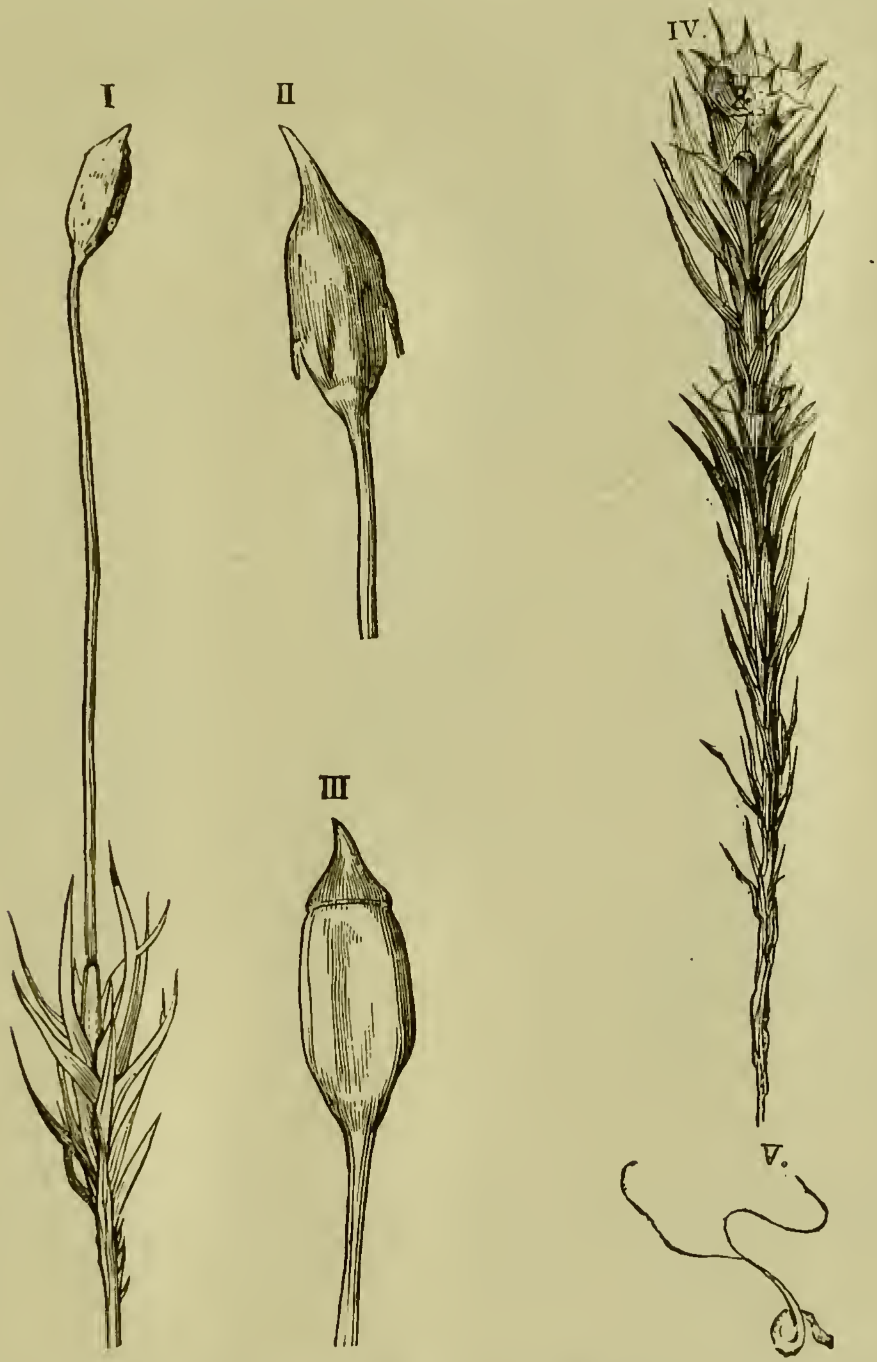


Fig. 427.—Hair-moss, *Polytrichum commune*: I. plant with sporangium (magnified); II. sporangium with calyptra, III. without calyptra (magnified); IV. plant with perigonium surrounding the antheridial receptacle, and exhibiting prolification (magnified); V. antherozoid (× 1000).

vided with peculiar lamellæ; otherwise there is, as a rule, no special epidermal tissue with stomata, hairs, &c., even when this is found on the stem and reproductive organs. There are never true roots; the nutriment being absorbed through rhizoids. At the apex of the stem, or growing laterally on it, are often several leaves of a somewhat different form to the rest, forming the *perigonium*, a kind of envelope which protects the organs of reproduction growing within it (Fig. 427, IV.).

The organs of reproduction at first altogether resemble those of the Hepaticæ; but in the course of their development the following differences arise:—The archegonium of Mosses is ruptured by the young *sporogonium*, and usually in such a way that the lower part remains as a sheath or *vaginule*, while the remainder is elevated in the form of a cap or *calyptra*, surmounting the capsular 'fruit,' the urn, theca, or *sporangium*; and is finally carried away by the wind, rain, or other accident. The axis of the sporangium is occupied by a central column or *columella*, around which the unicellular spores are formed. In order to allow these to escape, the sporangium, which varies greatly in form in the different genera, opens by means of a lid or *operculum*; less often, in the Andreæaceæ (Fig. 429), by four longitudinal slits, or, in the Phascaceæ, irregularly. The opening resulting from the operculum being thrown off is variable in form; its margin is either smooth (*gymnostomous*), or is furnished with two rows of cilia or teeth of beautiful form, constituting together the *peristome* (Fig. 430), the nature of which furnishes a character for the classification of the genera. The antheridia are usually in groups, and are surrounded by an envelope of peculiar leaves, the *perigonium* (Fig. 427 IV.). Among the antheridia are filiform structures—possibly abortive leaves—the *paraphyses*. [The antheridia produce a number of extremely minute antherozoids (Figs. 427 V., 428).] On germination the spore puts out first of all a prothallium, which is usually filiform, when it is called a *protonema*; and on it the young plant is developed.

Besides the reproduction by spores, Mosses are also propagated non-sexually by *gemmæ*, and by special shoots known as *stolons*. Those forms in which the growth is terminated by the production of antheridia or archegonia at the apex of the stem often exhibit *prolification* of the bud, as in *Polytrichum* (Fig. 427 IV.). Axillary buds by the side of the sporangium or of the antheridia often develope also by a process of renewal, forming growths known as *innovations*.

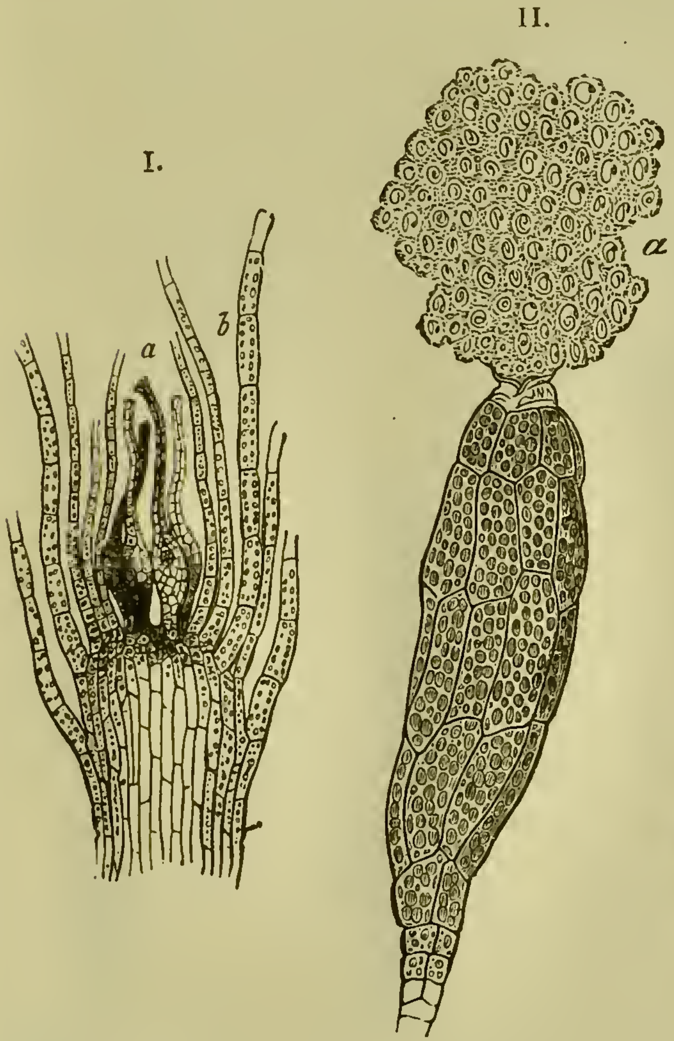


FIG. 428.—*Funaria hygrometrica*: I. longitudinal section through the upper part of a plant with archegonia *a* and leaves *b* (× 400); II. antheridium bursting, and allowing the antherozoids *a* to escape (× 350).

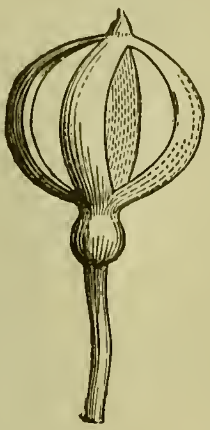


FIG. 429.—*Andreæa alpestris*: sporangium bursting into four valves.

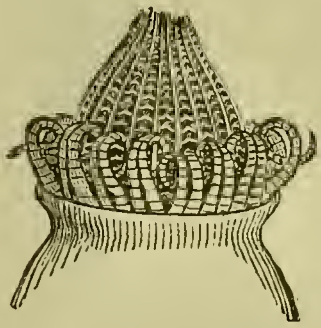


FIG. 430.—Mouth of the sporangium of *Fontinalis antipyretica*, with an inner and outer peristome (after Schimper, × 30).

The Musci are divided into two sub-classes, as follows :—

1. SPHAGNACEÆ. *Bog-mosses.*

According as the Sphagnaceæ grow in water or on a solid substratum, they form a filiform or thalloid prothallium. [The globular sporangium is elevated on a short stalk or *pseudopodium*, which is not, however, homologous with the seta of true mosses.] The mode of growth is shown in Fig. 431. [This section includes the single genus *Sphagnum*].

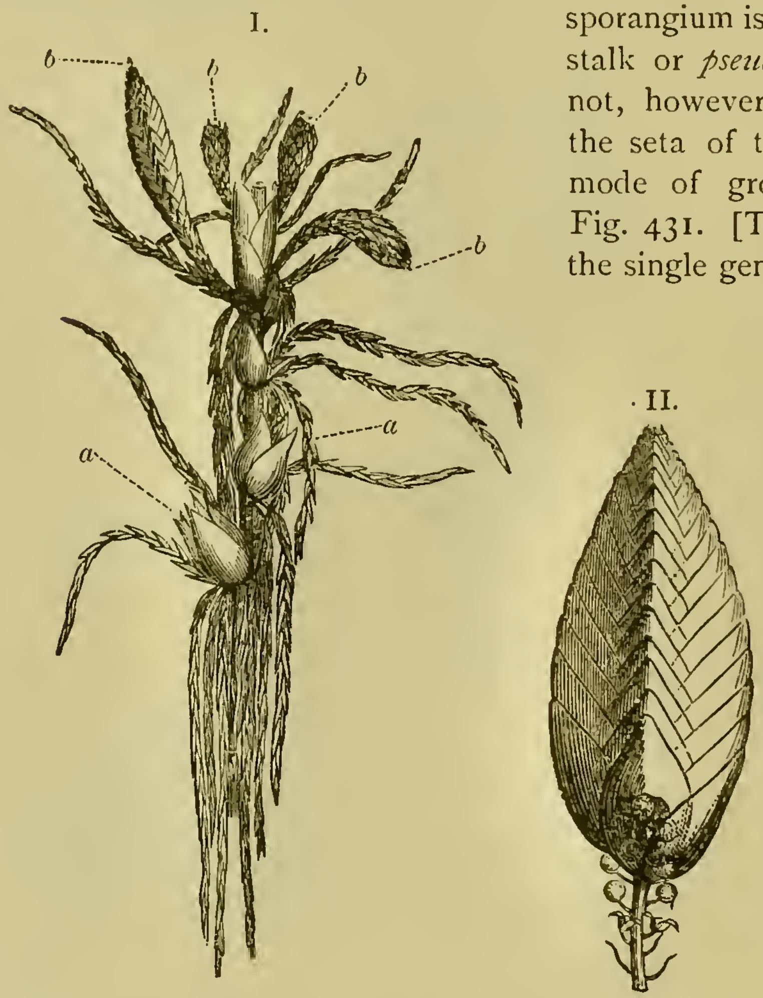


FIG. 431.—*Sphagnum acutifolium* ; I. part of the stem with two sporogonia *a* and four antheridial receptacles *b* (after Schimper, × 3) ; II. an antheridial receptacle separated, with the perigonial leaves removed from the lower part so as to expose the stalked globular antheridia (more strongly magnified).

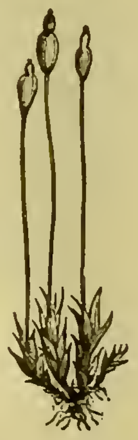


FIG. 432. — *Splachnum ampullaceum* (Acrocarpi ; magnified).

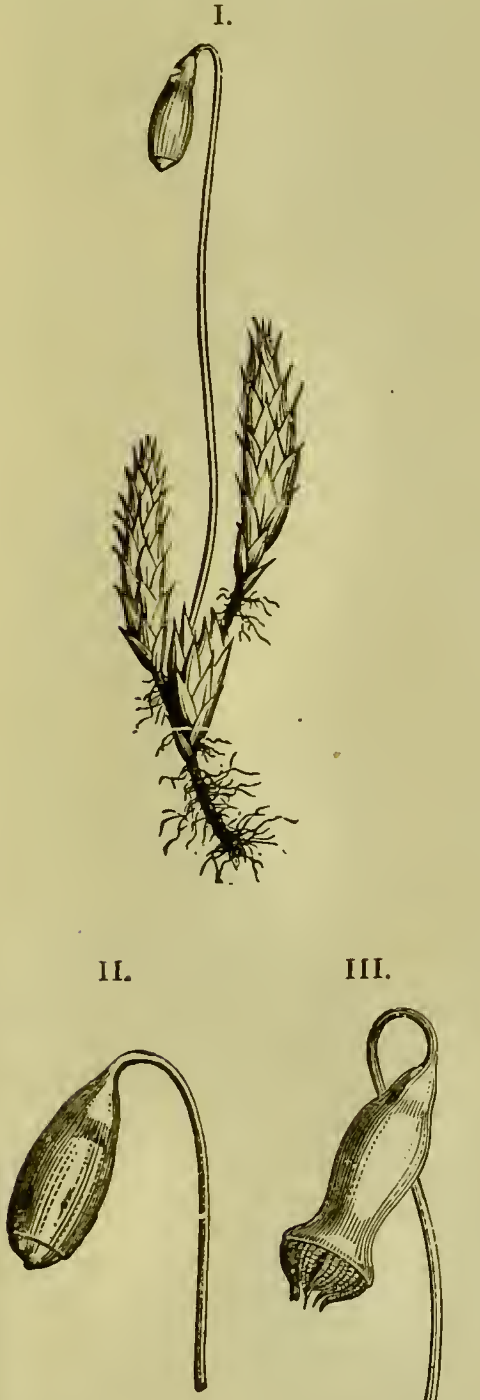
2. BRYINEÆ. *True Mosses.*

Prothallium always filiform (protonema) ; only one kind of spore.

1. *Andreæaceæ.* The ripe sporangium opens by four longitudinal slits (Fig. 429).

2. *Phascaceæ.* [The roundish sporangium ruptures the calyptra laterally, without raising it up as a cap ; no operculum.]

3. *Bryaceæ.* [The sporangium is covered by a calyptra, and opens by throwing off an operculum.]



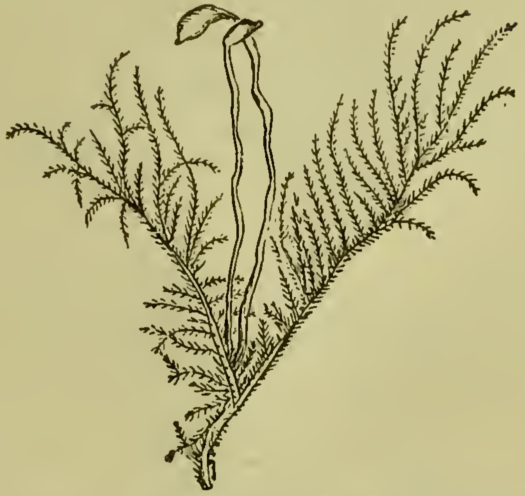


FIG. 434.—*Hypnum filicinum* (Pleurocarpi; natural size).

FIG. 433.—*Bryum argenteum* (Acrocarpi); I. the whole plant (magnified); II. sporangium with operculum; III. sporangium burst, showing the peristome (more strongly magnified).

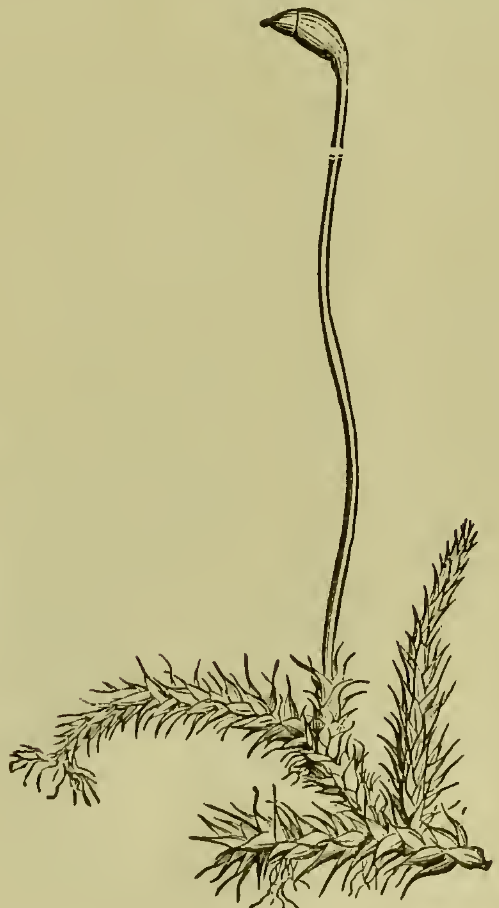


FIG. 435. —*Hypnum populeum* (Pleurocarpi; magnified).

a. Acrocarpi. The sporangium springs from the apex of the main stem or its branches; *e.g. Funaria, Splachnum, Dicranum, Bryum, Polytrichum*, &c. (Figs. 427, 432, 433).

b. Pleurocarpi. The sporangium springs from the axil of a leaf; *e.g. Hypnum, Fontinalis*, &c. (Figs. 434, 435).

Mosses are generally distributed over the surface of the earth; only a few grow in water. They are of no economical importance; the species of *Sphagnum* contribute largely to the formation of peat.

ISOSPOROUS VASCULAR CRYPTOGAMS

Class VII. *Filicales.*

Ferns have usually a simple or branched creeping rhizome, either below or above the surface (Fig. 436); less often an erect woody stem, which is then always simple (Fig. 437). In either case the stem always continually dies off slowly at its lower end, or becomes lignified. Large numbers of adventitious roots provided with root-hairs break out from the lower part of the stem or from the rhizome, while the upper part frequently puts out aërial roots. The stem is covered, when young, with an epidermis provided, where above-ground, with stomata. The subjacent cortical tissue either consists entirely of thin-walled parenchymatous cells, or becomes differentiated into an outer cortex consisting of thick-walled cells, and a thin-walled parenchymatous inner cortex (Fig. 438 R′ and R″), the latter passing over gradually into the fundamental tissue. The fibrovascular bundles of the entire plant are in direct communication with one another above and below. They divide and ramify in the stem, forming a complete network, and send out branches into the leaves. In the roots, on the contrary, the bundles coalesce into a single central or axial vascular bundle. The separate bundles, as seen in transverse section, are sometimes roundish and sometimes ribbon-shaped, and are usually separated from the cortical and medullary cells by a *vascular bundle-sheath* (Fig. 438 II., s), consisting of narrower thick-walled cells, which again is often invested by a layer of brown sclerenchymatous cells (*x*). The vascular

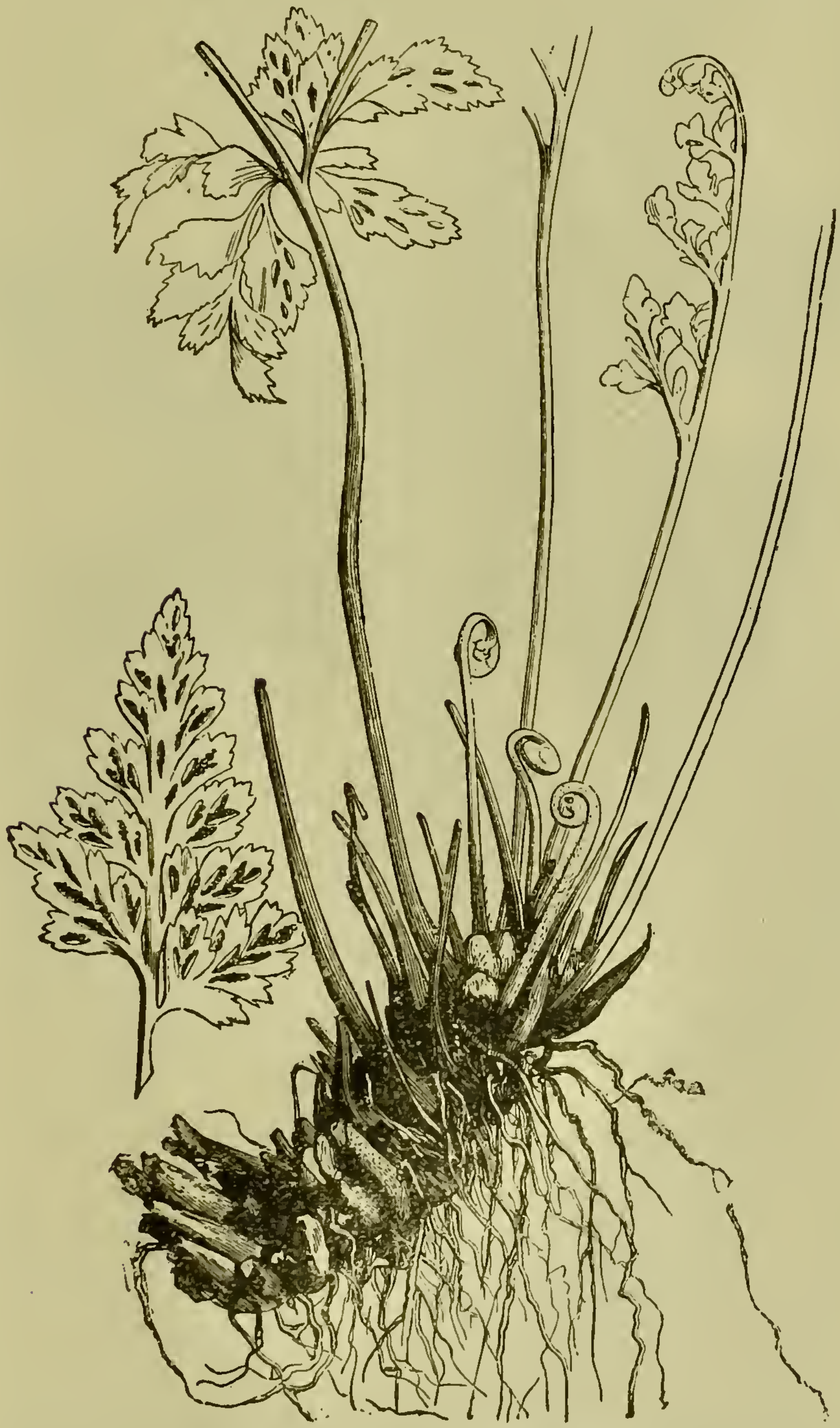


FIG. 436.—Black spleenwort, *Asplenium Adiantum-nigrum*, showing a part of the rhizome (natural size, with a single pinna magnified).

bundles are strongly developed, and are always *closed*, consisting of xylem and phloëm only, without any intermediate cambium. The xylem is composed chiefly of *scalariform vessels* (Fig. 69, p. 46), the phloëm of parenchymatous cells

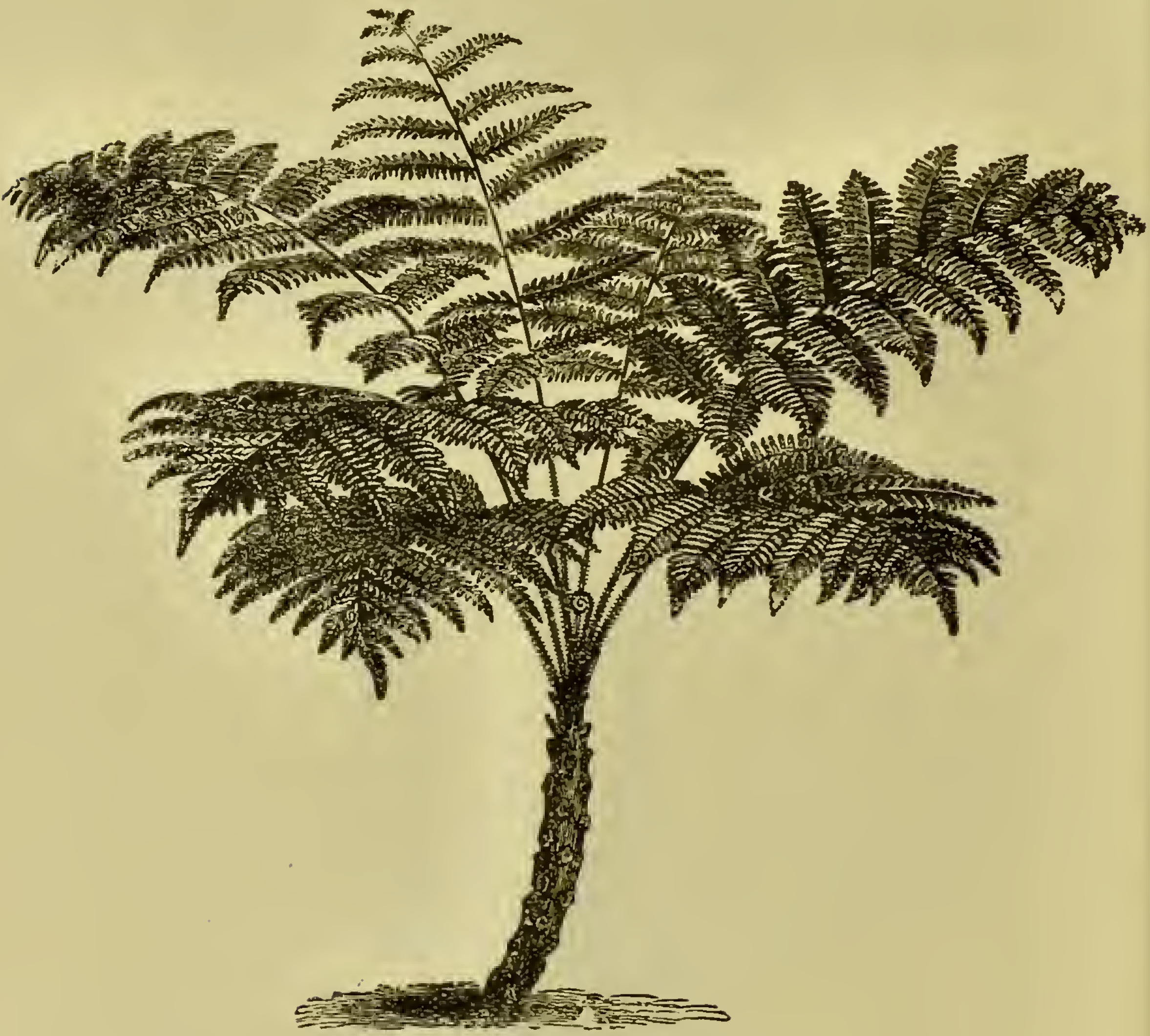


FIG. 437.—*Alsophila aculeata*; a tree-fern (greatly reduced).

containing starch, bast-fibres, and sieve-tubes, and generally completely enclosed, the xylem in the form of a cylinder, constituting the kind of bundle known as *concentric*. The apex of the stem is always occupied by a single clearly distinguishable *apical cell*, by the continuous division of which the fundamental tissue is produced.

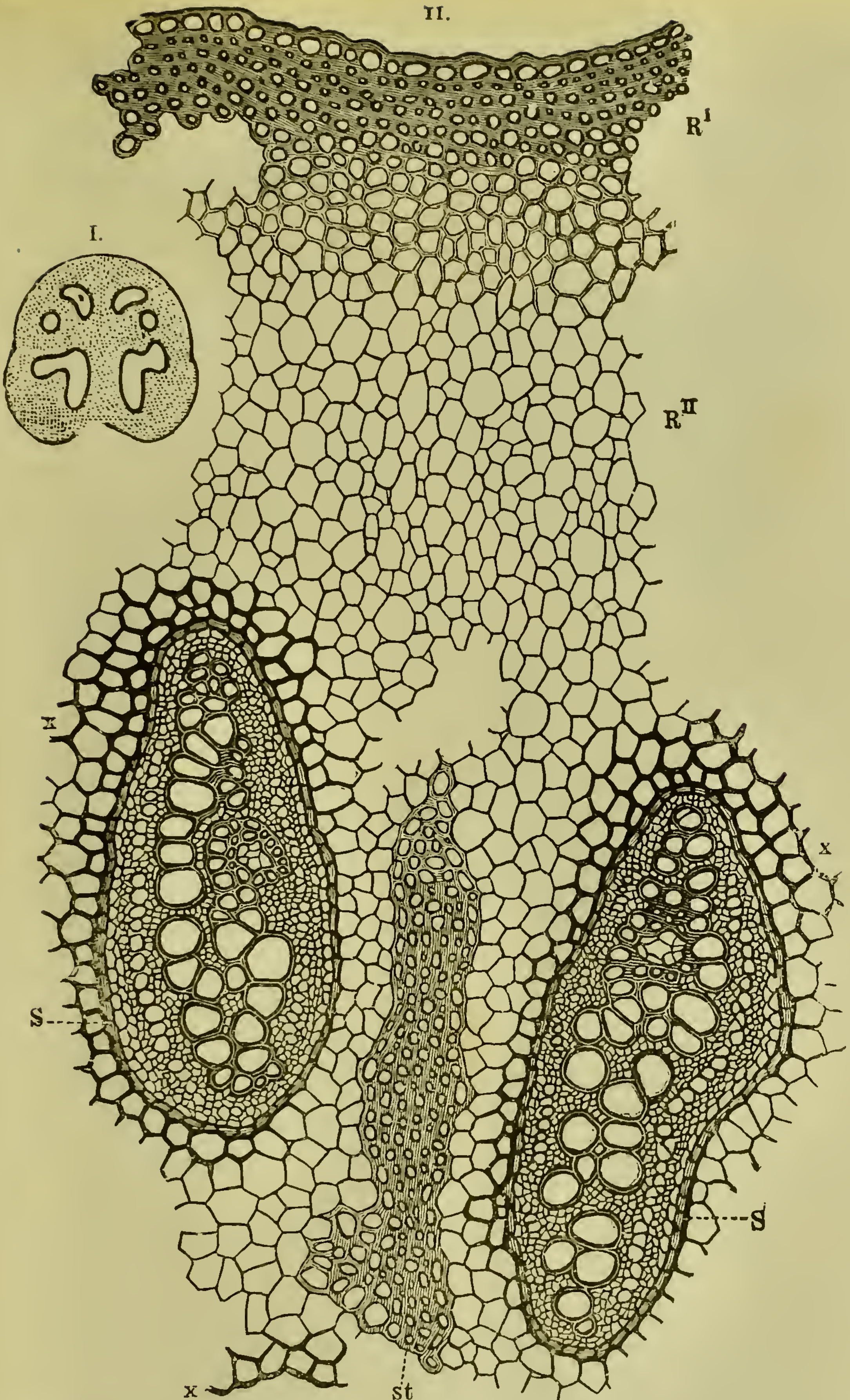


FIG. 438.– I. Transverse section through the rhizome of the common brake, *Pteris aquilina*, showing the distribution of the vascular bundles (natural size); II. a part of the preceding figure: O epidermis; R′ thick-walled, R″ thin-walled cortical tissue; S vascular bundle-sheath; *x* sclerenchymatous cells outside the latter; *st* bundles of prosenchymatous cells (× 110).

The leaves of Ferns are commonly known as *fronds.* They originate, like those of higher plants, as small cellular elevations beneath the growing point of the stem, but increase in length, like branches, at their apex, below which the lamina is then formed. In all the families except the Ophioglossaceæ, the leaves are rolled up, when young, in a circinate manner; after maturity, they are thrown off periodically. They are produced only at the apex of the stem. Their form varies greatly, from lanceolate and entire to doubly or trebly pinnate. Except in the Hymenophyllaceæ they are almost always composed of several layers of cells, which very commonly separate into two clearly distinguishable laminæ, the upper one consisting of cylindrical cells placed vertically to the surface, and fitting more or less closely to one another, the lower of a looser tissue formed of cells of a more spherical form. Both sides of the leaf are covered by an epidermis provided with numerous stomata. The stem and the rachis of the leaves are clothed, in most species, with brown dry lanceolate or hair-like epidermal structures of a thin membranous texture, the *paleæ* or ramenta.

III.

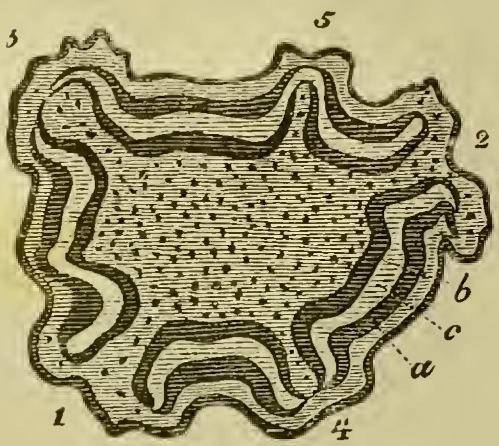


FIG. 438 III.—Transverse section through the stem of a tropical Fern: *a b* layers of lignified nearly solid parenchymatous cells, surrounding the vascular bundle *c*; 1–5 the points of attachment of five leaves already thrown off (natural size).

The *sporangia* are arranged in masses at definite spots, usually on the under side of the leaf, and are usually trichomes or outgrowths of its epidermis (Fig. 439) developed from a single cell, less often from a group of cells; while in the Ophioglossaceæ they are placed on a separate branch of the leaf. The separate *sori* [or collections of sporangia] vary in form and arrangement, and afford distinguishing characteristics for the genera. They are occasionally naked, as in *Polypodium* (Fig. 439 v.) ; but are more often covered by a membranous skin, the *indusium* [which is usually an extension of the epidermis] (Fig. 439 I.). In

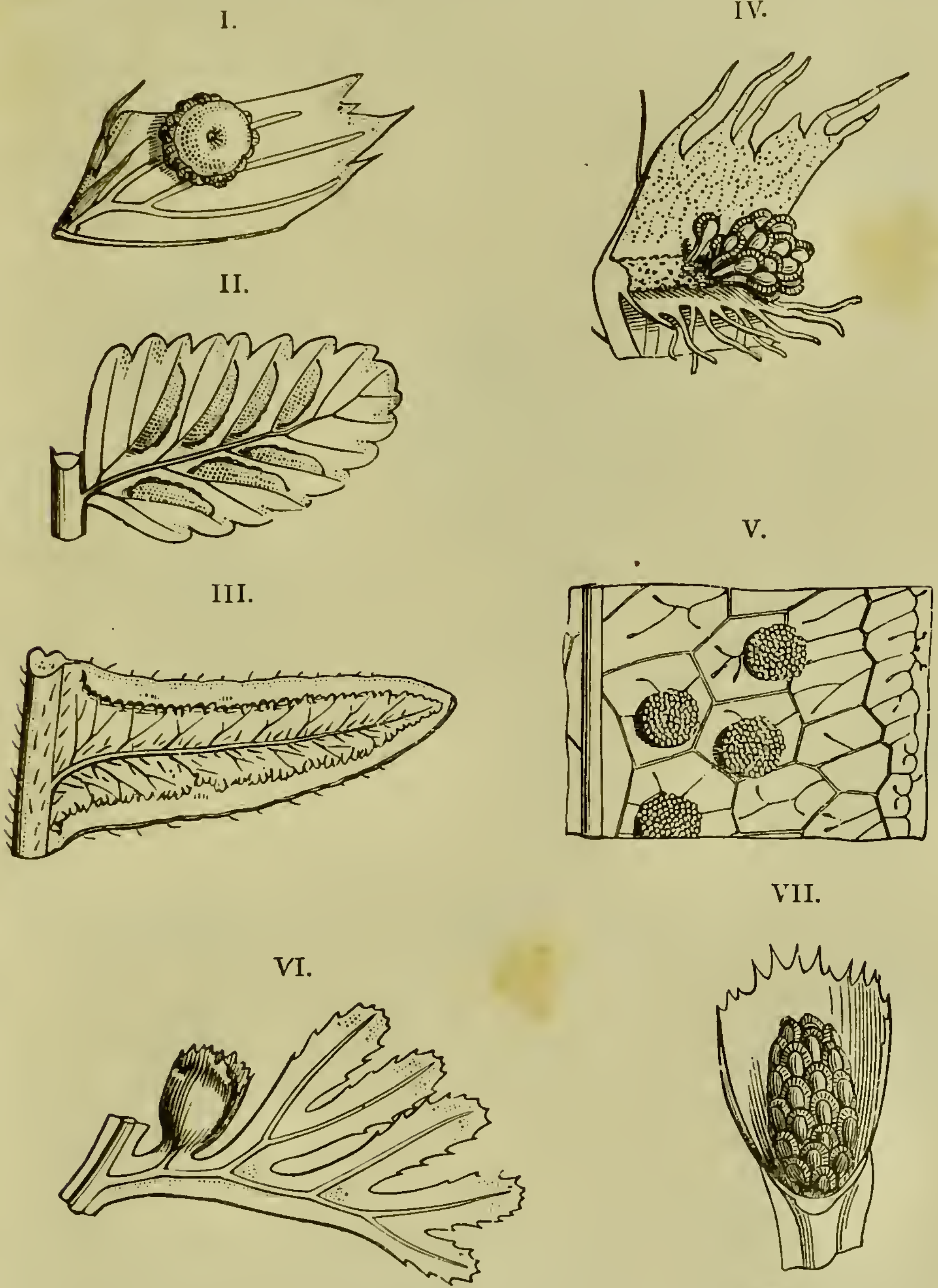


FIG. 439. — Pinnæ of fronds of Ferns with sori ; I. *Aspidium*, the sporangia visible at the margin of the peltate indusium ; II. *Asplenium* : III. *Pteris aquilina* ; IV. the same with the indusium thrown back to show the mode of attachment of the sporangia ; V. *Polypodium*, indusium wanting ; VI. *Hymenophyllum* or filmy fern : VII. the same ; the indusium partly removed to show the sporangia (all magnified).

most Ferns the sporangia are provided with an elastic ring, the *annulus*, running over the apex, which [by its contraction] causes the sporangium to burst [to allow the escape of the spores] (Fig. 440 I.); less often it surrounds the sporangium in a horizontal or oblique direction (Fig. 440 II. III.). On germinating, the spore first gives rise to a green thalloid

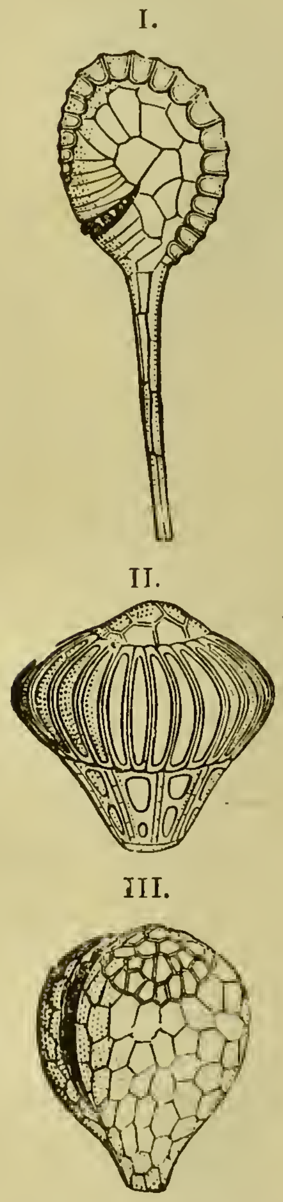


FIG. 440. — Sporangia of Ferns; I. *Aspidium* with vertical annulus: II. *Trichomanes* with horizontal annulus; III. *Osmunda regalis*, royal fern, with incomplete annulus (all greatly magnified).

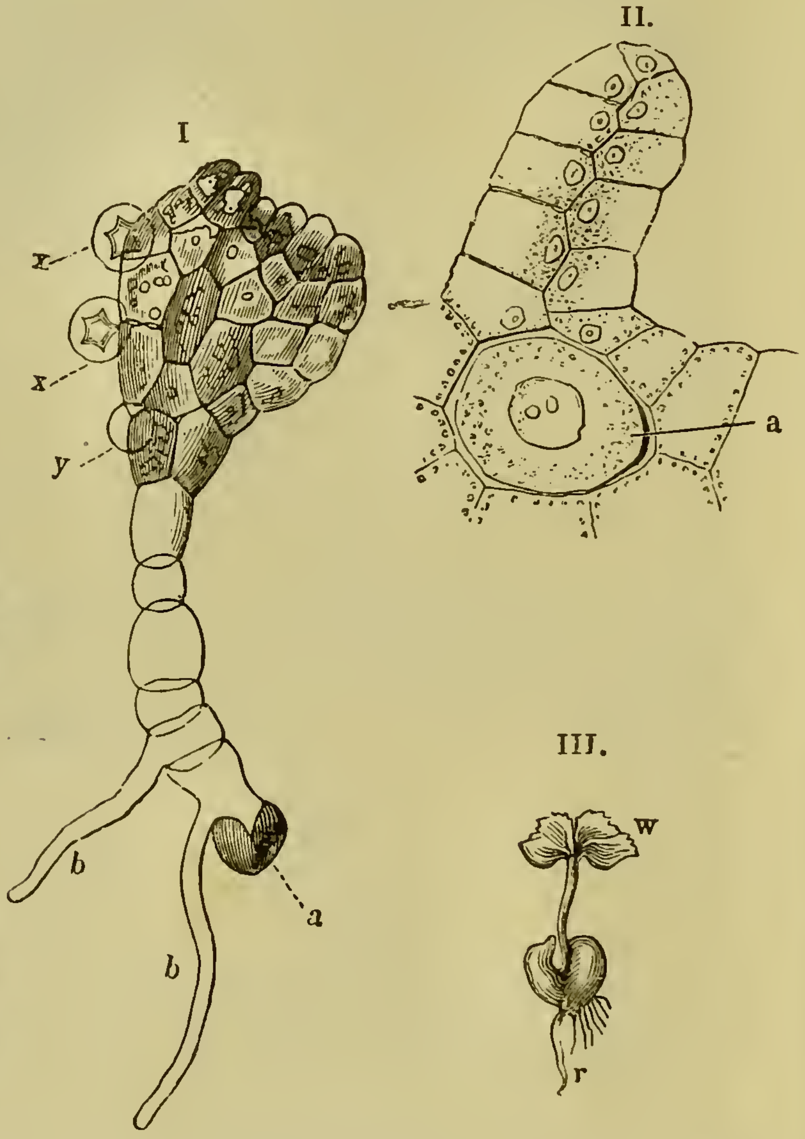


FIG. 441.—Reproduction of a Fern, *Pteris serrulata*; I. the prothallium proceeding from the spore; *a* spore, *b* rhizoids, *x y* antheridia (× 80); II. an archegonium near the period of opening, *a* central cell (× 400); III. the young plant springing from the cordate prothallium; *w* first leaf, *r* first root (natural size).

leaf-like often kidney-shaped structure, lying flat on the surface of the ground, the *prothallium* (Fig. 441 III.), which puts out rhizoids from its under side, and forms the archegonia and antheridia among them. In the latter are produced the ciliated antherozoids (Fig. 442); from the former, which agree in almost all points with the archegonia of Mosses, the young plant is developed, after the fertilisation of the oosphere by the antherozoids ; the prothallium then disappearing. [The central cell of the archegonium divides first into four cells, of which the two lowest subdivide and become imbedded in the substance of the prothallium. The two upper of the four cells also subdivide, one developing into the rhizome, the other into the first rootlet of the young Fern.]

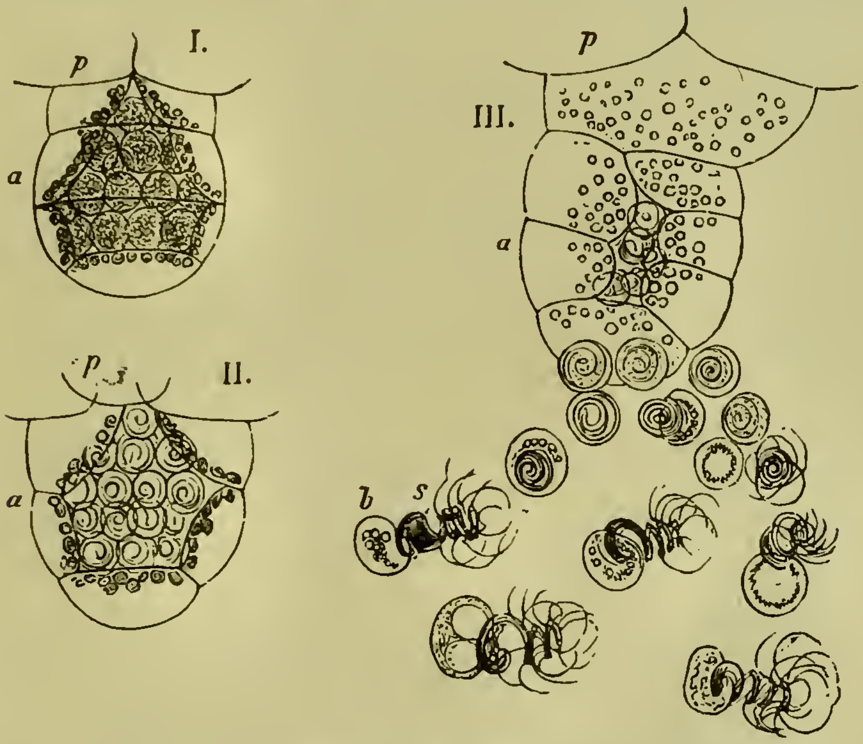


FIG. 442.—Antheridia of *Adiantum capillus-veneris*, maidenhair fern ; I. not yet mature ; II. the antherozoids fully developed ; III. the antherozoids escaping from the burst antheridium ; *p* prothallium, *a* antheridium, *s* antherozoids, *b* mother-cell of an antherozoid (× 500).

An alternation of generations is very strongly marked in Ferns ; the first [sexual] generation includes the formation of the prothallium and sexual organs ; the second [non-sexual] generation the spore-producing Fern-plant itself.

[A remarkable exception to the ordinary alternation of generations is presented by the phenomenon of *apogamy*, as seen in *Pteris cretica* and some other ferns, where antheridia only are formed on the prothallium, from which the non-sexual generation springs in a purely vegetative manner. The converse phenomenon of *apospory* or development of a prothallium directly on the frond, has also been observed. Ferns are also reproduced by means of *gemmæ* which grow on the stalk or surface of the leaves.

Ferns have been applied to but very few economical uses. The rhizome of the 'male fern,' *Nephrodium filix-mas*, and of the common polypody, *Polypodium vulgare*, and the paleæ of a Sumatran species, *Cibotium glaucescens*, are used in medicine as vermifuges. Abundant remains of Ferns are found in the fossil state, for which see Chapter VIII.

[The Filicales are conveniently divided in three orders, viz. :—

I. FILICES or true Ferns. Prothallium above-ground and green. Leaves not stipulate, circinate in vernation. Sporangia formed from single epidermal cells, not coherent, on the back or margin of the leaves. They include the following sub-orders :—

1. *Hymenophyllaceæ*. Sporangia formed on a prolongation of a vein projecting beyond the margin of the leaf, and surrounded by a cup-shaped indusium. Annulus oblique or transverse, and dehiscence, therefore, longitudinal : leaves often very thin and delicate : *Hymenophyllum*, *Trichomanes*, *Loxsoma*, &c. (Figs. 439 VI., VII., 440 II.)

2. *Gleicheniaceæ*. Sporangia sessile, with a complete transverse annulus : dehiscence longitudinal : *Gleichenia*.

3. *Schizæaceæ*. Sporangia sessile or shortly stalked ; annulus complete, forming an apical cap-like zone ; dehiscence longitudinal : *Schizæa*, *Anemia*, *Lygodium*.

4. *Osmundaceæ*. Sporangia shortly stalked ; annulus running round one side only ; dehiscence longitudinal. Upper part of fertile fronds marked by the absence of parenchyma between the veins which bear the sori : *Osmunda*, *Todea*. (Fig. 440 III.)

5. *Cyatheaceæ*. Annulus complete, oblique, eccentric ; dehiscence transverse ; sorus generally on a strongly developed receptacle : *Alsophila*, *Hemitelia*, *Cyathea* ; most tree-ferns. (Fig. 437).

6. *Polypodiaceæ*. Annulus vertical and incomplete ; dehiscence transverse : *Acrostichum*, *Polypodium*, *Adiantum*, *Pteris*, *Blechnum*, *Asplenium*, *Scolopendrium*, *Aspidium*, &c. (Fig. 439 I–V., 440 I.)

II. MARATTIACEÆ. Prothallium above-ground and green. Leaves usually of great size, stipulate, and circinate in vernation. Sporangia

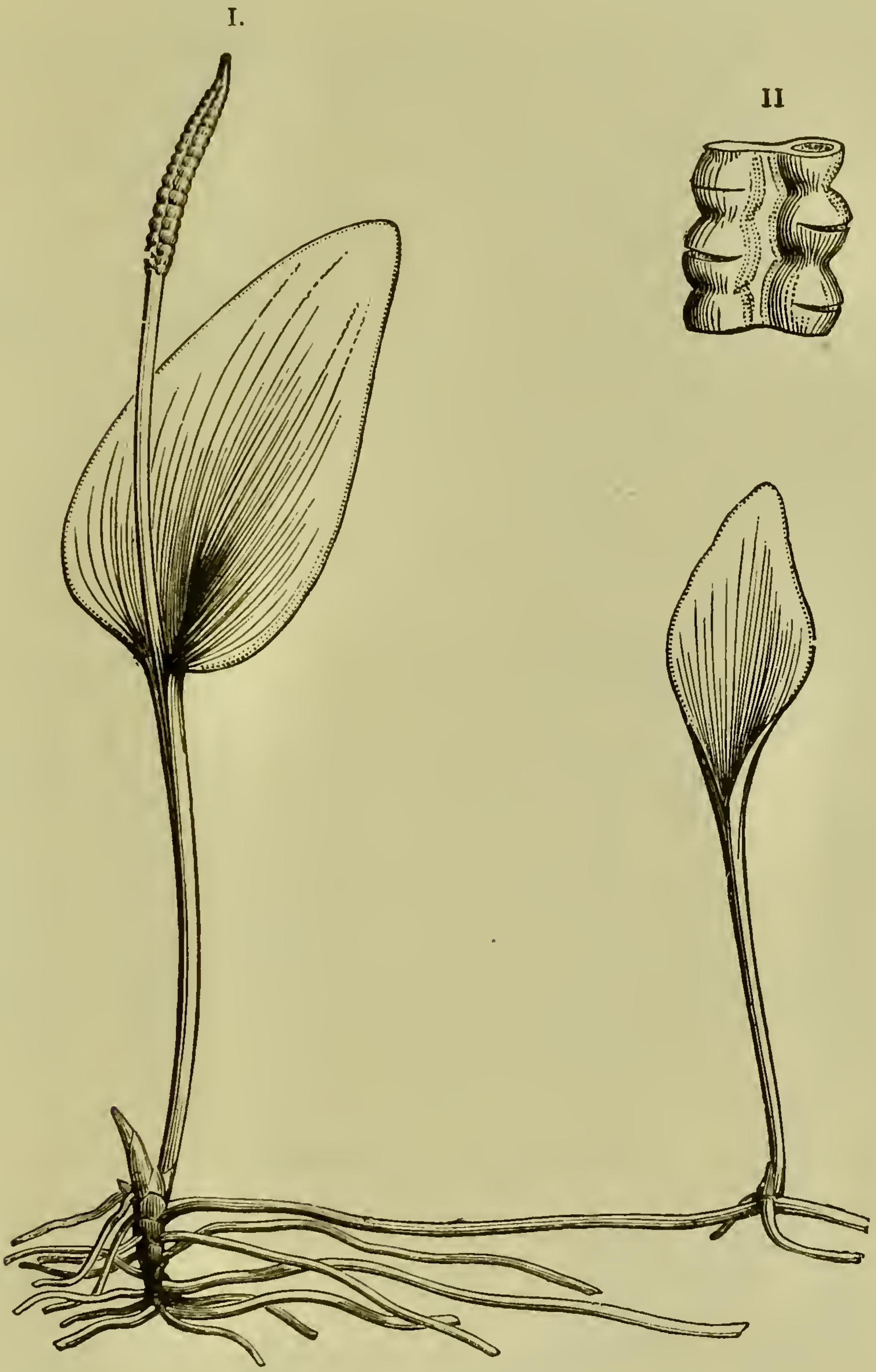


FIG. 443.—Adder's-tongue, *Ophioglossum vulgatum* : I. whole plant (natural size) ; II. a part of the fertile portion of the leaf with four sporangia in the act of bursting (magnified).

on the back of the leaves, coherent into a many-celled sorus, opening by a pore, and each developed from a group of cells: *Marattia*, *Danæa*, *Kaulfussia*, *Angiopteris*.—Ed.]

III. Ophioglossaceæ. This order is distinguished by its underground prothallium, which is destitute of chlorophyll; by the mode of development and the form of the sporangia; and, finally, by the stem never branching. The primary root seldom branches; and the small flat stem is enclosed by the sheathing base of the leaf. The number of leaves, which are always annual, is small; our two native species, *Ophioglossum vulgatum* (Fig. 443), and *Botrychium Lunaria*, never producing more than one each year. The leaves are also remarkable for the slowness of their growth; those of the latter species requiring four years for their development, the first three of these being spent entirely beneath the soil. As soon as the plant has attained a certain age, the leaf branches, one half developing into a receptacle or spike of sporangia, [the other into the green lamina of the leaf]. The sporangia are developed from a group of cells, are two-valved, and without an annulus. In *Ophioglossum* they are arranged in two rows in a simple spike (Fig. 443 i., ii.), and are coherent; in *Botrychium*, on the contrary, they are distinct, and form a branched spike or panicle. The tetrahedral spores produce, on germination, prothallia, on which are developed the antheridia and archegonia. In *Ophioglossum* there is also a vegetative mode of reproduction by means of adventitious buds on the roots (Fig. 443 i.). The prevalent form of tissue is parenchymatous fundamental tissue, consisting of long, nearly cylindrical cells, thin walled and full of sap, and with large intercellular spaces. Both sides of the leaves are covered by an epidermis provided with numerous stomata. The vascular bundles form a network in the stem, the tissue which occupies the space between the meshes being frequently changed into scalariform vessels, so that the stem then forms a closed hollow cylinder. This often takes place only on one side.

CLASS VIII. *Equisetales.*

This class is composed of the single order *Equisetaceæ*, which is made up of the single genus *Equisetum* or 'Horse-tails.' The aërial stem springs from a creeping rhizome which produces at its nodes a number of adventitious roots. The stem is herbaceous, usually furrowed, simple or branched, jointed, and provided at the joints or nodes with

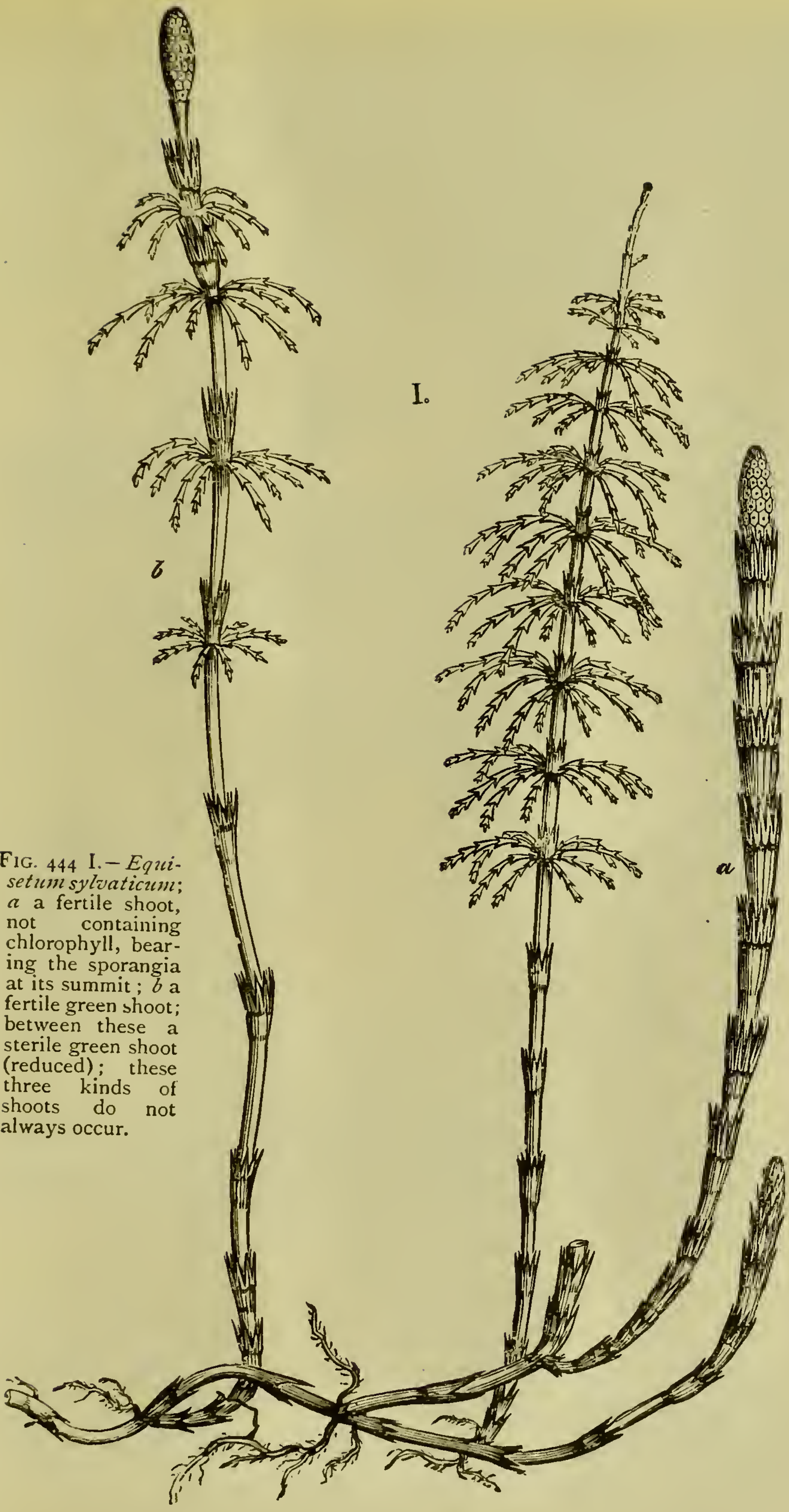


Fig. 444 I.—*Equisetum sylvaticum*; *a* a fertile shoot, not containing chlorophyll, bearing the sporangia at its summit; *b* a fertile green shoot; between these a sterile green shoot (reduced); these three kinds of shoots do not always occur.

toothed *sheaths*, formed by the coalescence of the leaves at their base. The habit of the plant depends on this mode of formation of the leaves, and on the verticillate arrangement of the branches which spring from buds in the cortex (Fig. 444 I.). The stem, rhizome, and root are all derived from a single apical cell, which divides into three series of segments. In the internal structure of the stem the *air-cavities* are of great importance. Its centre is occupied by a large central air-cavity (Fig. 445 A, *c*) ; and in the surrounding ring of tissue, which is often rather narrow, there is almost

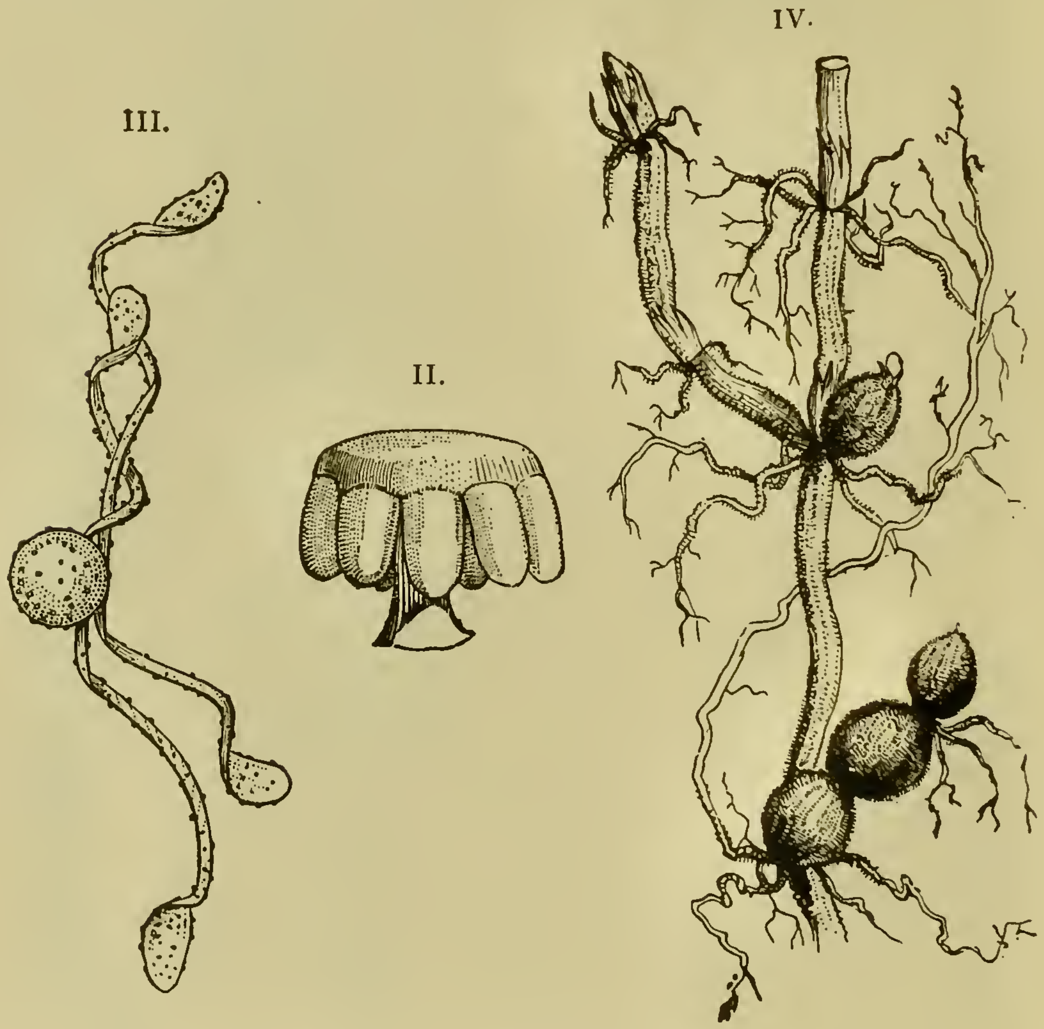


Fig. 444 II.—A peltate scale bearing the sporangia on its inner side facing the stem, five being visible (magnified); III. spore with the elaters unrolled which were previously coiled spirally round it (greatly magnified); IV. *E. fluviatile*; rhizome covered everywhere with root-hairs, and having four tubers about the size of hazel-nuts which would, under favourable conditions, develope into new stems.

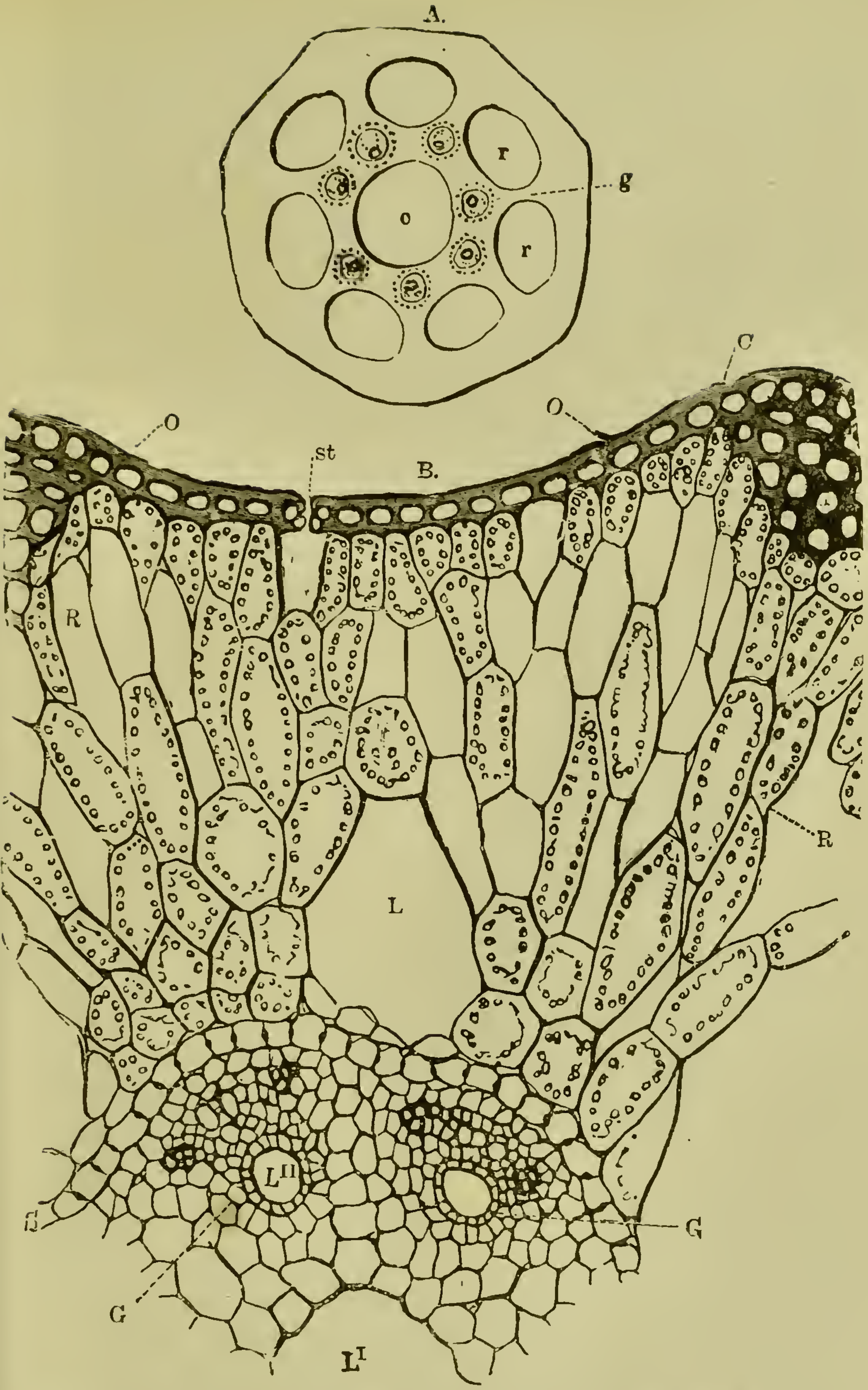


FIG. 445. –A. Transverse section through the rhizome of *Equisetum littorale*; *g* vascular bundle surrounded by a sheath ; *o* central. *r* cortical air-cavities (× 26); B. transverse section through a young stem of *E. sylvaticum* ; O epidermis; C collenchyma ; R cortical parenchyma, many of the cells containing chlorophyll; S vascular bundle-sheath ; G vascular bundle ; L cortical air-cavity ; L' central air-cavity ; L'' air-cavity of the vascular bundle ; *st* stoma (× 150).

always a cortical air-cavity (Fig. 445 A, *r*) between each pair of vascular bundles *g*. In addition, there often occur also the so-called 'essential' air-cavities (Fig. 445 B, L′) in the vascular bundles. The stomata (Fig. 445 B, *st*) are usually placed in a single or in several rows between the elevated ridges of the stem. The cortex consists of thin-walled or of only moderately thick-walled parenchyma. It is separated on the inside from the vascular bundles by a sheath which sometimes encloses all the bundles together (Fig. 445 B, S); while at other times each separate bundle is surrounded by a sheath (Fig. 445 A, *g*). The vascular bundles ascend in a vertical direction, and parallel to one another, through the internodes, and form annular coils in the nodes. [They are always 'closed' bundles, containing no cambium]. Two other groups of vascular cells are found on the cortical side of the bundle. The bast-portion contains three elements: parenchyma, bast-fibres, and sieve-tubes; it lies between the four groups of vascular cells and the vascular bundle-sheath. In the root is an axial bundle of vascular cells surrounded by elongated parenchymatous cells, with which sieve-tubes and bast-fibres are intermixed. The sporangia are capsules placed on the under side of scales belonging to the fructification (Fig. 444 II.). The fructification or receptacle is often placed on special shoots which are distinguished by their external form and by their brown colour from the sterile green stems (Fig. 444 I.). The spores are provided with two hygroscopic bands or *elaters* (Fig. 444 III.), only loosely attached to them, [formed by the splitting into narrow strips and the partial detaching of the *exospore* or outermost of the three coats of the spore, and serving, by their hygroscopic properties, to assist in their dissemination]. On germination the spore gives rise first to a flat prothallium, upon which are produced the antheridia and archegonia (Fig. 446); most species of *Equisetum* are diœcious, the female being many times larger than the male prothallium. In the antheridia are developed a very large number of motile antherozoids ; in the archegonium is a single central cell containing an oosphere, which, after impregnation, developes gradually into the young plant. The alternation of generations is therefore precisely similar to that of Ferns. The Equisetaceæ are also propagated in a vegetative non-sexual manner, by means of subterranean stolons and tubers (Fig. 444 IV., p. 320).

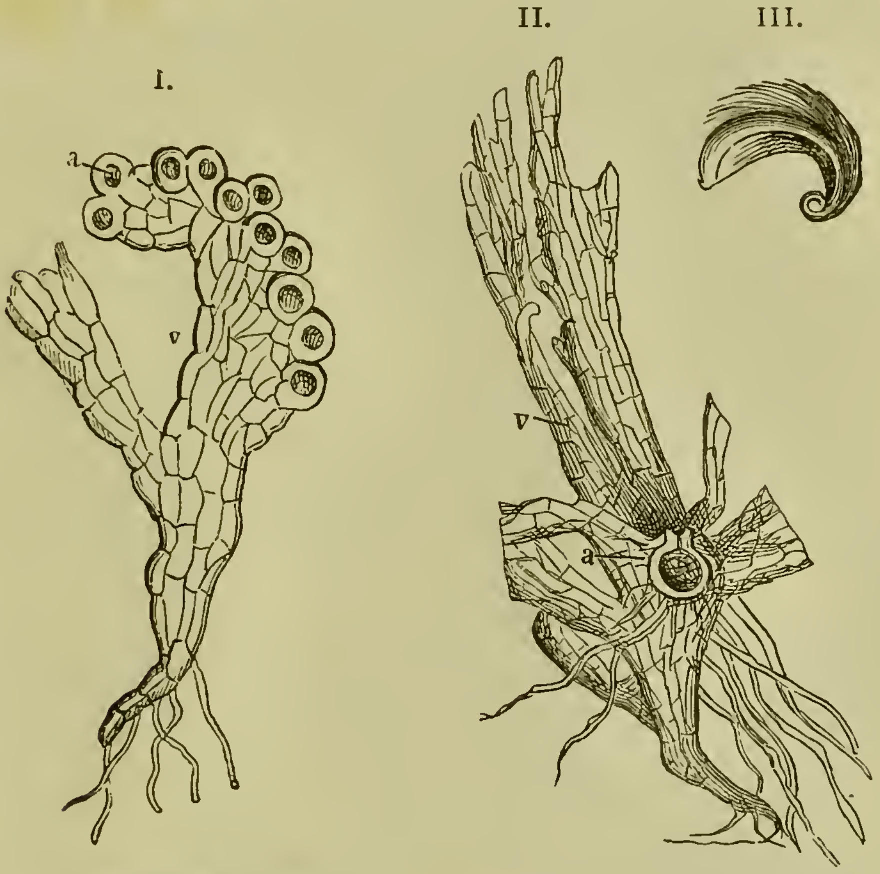


FIG. 446.—*Equisetum maximum* : I. prothallium *v* with eleven antheridia *a* (× 30); II. prothallium *v* with archegonium *a* (× 30) ; III. an antherozoid (× 500).

The class includes only a single genus, *Equisetum*. A quantity of silica is deposited in the stems, and especially in the epidermis ; *E. hyemale* being on this account especially used as a substance for polishing, under the name of 'Dutch rushes.' *E. arvense* is a troublesome weed. [*Calamites* are the stems of fossil Equisetaceæ ; large plants of this order probably formed a great proportion of the vegetation during the carboniferous period. See also Chapter VIII.]

CLASS IX. *Lycopodiales.*

The plants belonging to this class are characterised by having minute leaves, traversed by a single fibrovascular bundle. The larger number of species belong to the genus *Lycopodium*, with procumbent stem which repeatedly dichotomises, and closely imbricate leaves. The exotic *Phylloglossum* and *Psilotum* are erect shrubs in which *cladodes* or leaf-like branches take the place of true leaves ; the latter genus is also destitute of true roots, their function being performed by underground branches of the stem. The fibrovascular bundles of the stem and root are very characteristic, forming a large axial cylinder, within which lie several bands of xylem enclosed in phloëm, without any cambium, the whole enveloped in a vascular bundle-sheath (Fig. 447). Between the epidermis and the fibrovascular cylinder is the parenchymatous fundamental tissue, or outer and inner cortex. Adventitious roots are given out from the forks ot the stem.

The sporangia are borne in the axils of the leaves, sometimes of those belonging to the ordinary branches, more often on special modified branches (Fig. 451 A, p. 330), which form a cone-like or spike-like kind of fructification. They are capsular bodies, bursting when ripe and containing a large number of minute spores. The spores on germinating give rise to a green prothallium of large size, which is more highly developed than that of other Vascular Cryptogams, and which bears both antheridia and archegonia. It has been but very rarely seen.

Several native species of *Lycopodium* are commonly known as 'stag's-horn moss' or 'club-moss.' Some species have been used as emetics or purgatives. The powder used by druggists for enveloping pills consists of the spores of a *Lycopodium*. The spores of several species contain a large amount of an inflammable oil, and are used for making artificial lightning. The fossil *Lepidodendron* and *Sigillaria* were the stem, and *Stigmaria* the root, of trees belonging to this class,

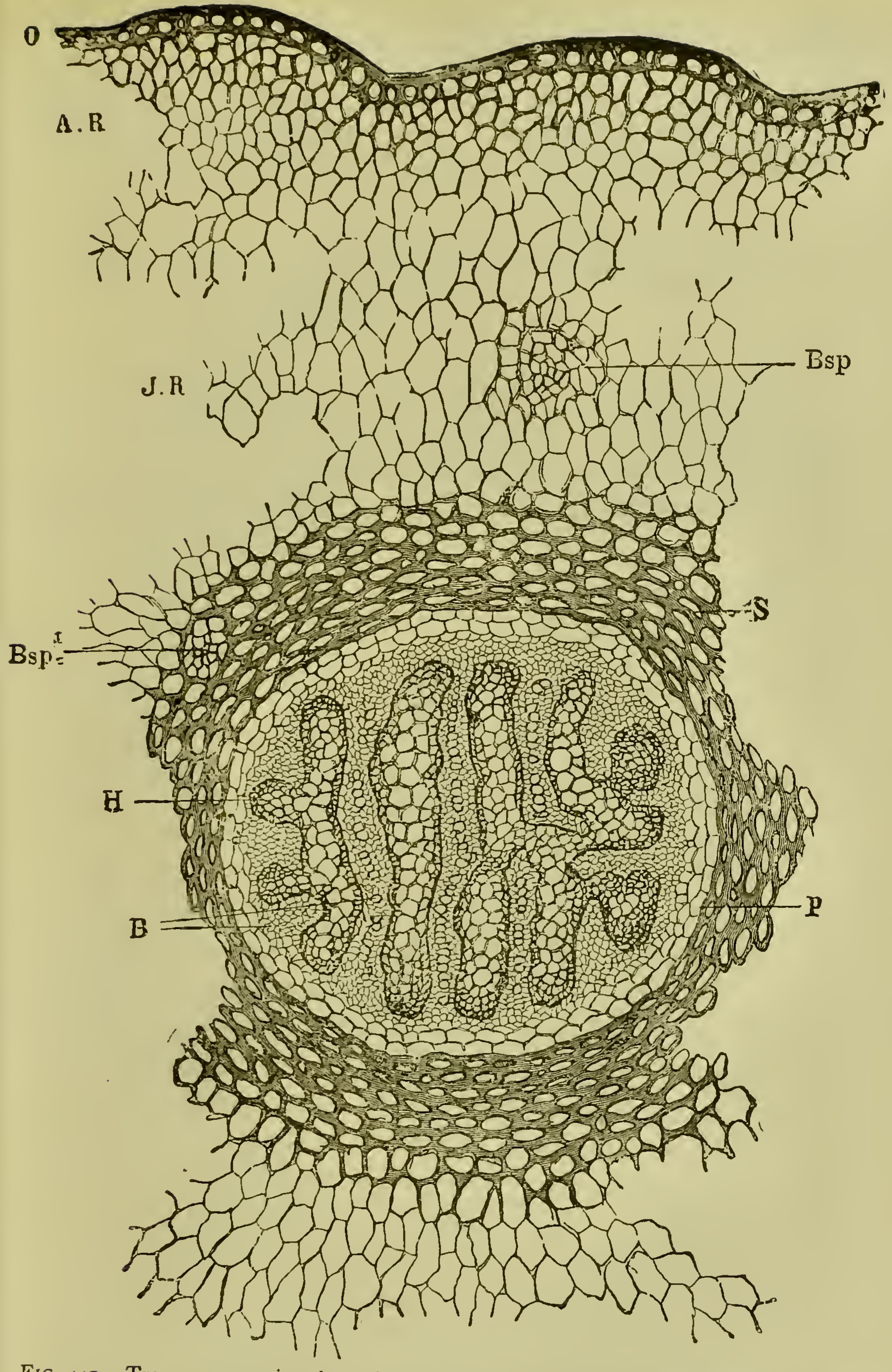


FIG. 447.—Transverse section through the stem of *Lycopodium annotinum*: O epidermis; A R outer cortex; J R inner cortex; S outer sheath; P vascular bundle sheath; H xylem-, B phloëm-portion of the vascular bundle; *Bsp*, *Bsp'* leaf-traces, or branches of the vascular bundle proceeding to the leaves (× 120).

or to the Selaginellaceæ, which flourished in the carboniferous period; *Lepidostrobus* is regarded, with great probabiliy, as their cone-like inflorescence. See also Chapter VIII.

HETEROSPOROUS VASCULAR CRYPTOGAMS.

CLASS X. *Rhizocarpeæ.*

The Rhizocarpeæ are plants floating on the surface or creeping along the bottom of water, and derive their name from the circumstance that their fructification is placed at the base of the leaves or between the fibres of submerged leaves. From their mode of life they have also been called 'Hydropterides' or Water-ferns. The stem has a simple vascular bundle in its axis, which branches with the stem and also passes into the leaves, and is surrounded by an annular layer of lignified cells and a parenchymatous cortex. The woody part (xylem) of the bundle consists of very thick-walled vascular cells, among which occurs here and there an elongated parenchymatous cell, while the phloëm-portion contains parenchyma, vessels, and bast-fibres. The root has also a central bundle, which is, however, surrounded by a sheath. The fructification consists of conceptacles or *sporocarps*, containing a number of *sporangia* collected in groups or *sori.* The sporocarps are either unilocular or multilocular, and are developed from metamorphosed leaves. The spores themselves are of two kinds: *megaspores*, and much smaller *microspores.* They are formed in different sporangia, *megasporangia* and *microsporangia*; the two kinds being found either in the same or in different sporocarps (Figs. 448 II., 450 I.). Only one megaspore in each megasporangium comes to maturity. The antheridia are either formed directly from the microspores, as in *Marsilea* and *Pilularia*; or, in *Salvinia*, the microspores germinate and produce spore-sacs, the apices of which develope into antheridia. At the apex of the megaspore is a papilla containing protoplasm, from which is developed the primary cell of the prothallium (Fig. 450 I. *a*). The contents of this apical papilla, which is enclosed in the *epispore*, a thick gelatinous coat resulting from the disorganisation of the remaining megaspores, divide, when the spore begins to germinate, into a central cell and several superficial ones.

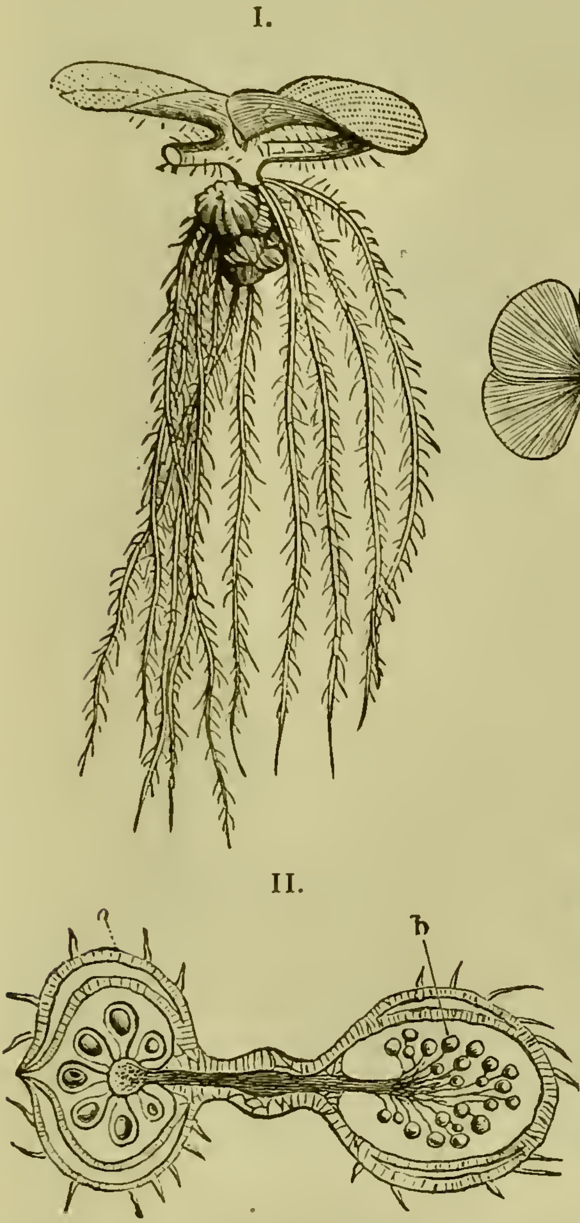


FIG. 448.—*Salvinia natans*: I. a piece of the plant with two aërial leaves, and one deeply divided root-like submerged leaf with sporocarps (natural size); II. a section through two sporocarps; *a* sporocarp with megasporangia, *b* with microsporangia (greatly magnified).

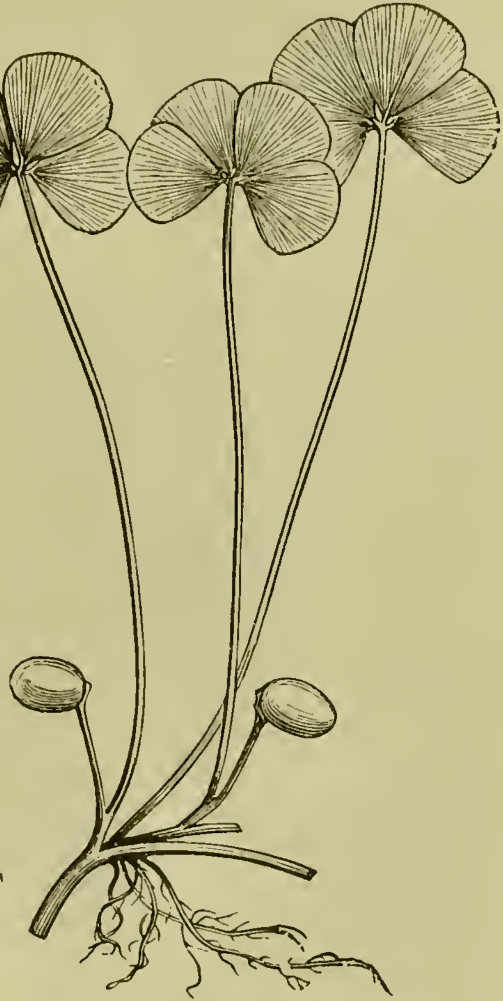


FIG. 449.—*Marsilea quadrifolia*, with two sporocarps (natural size).

The latter become filled with chlorophyll, and grow into a body which is placed like a cap on the apex of the megaspore, and then form the cells which immediately surround the central cell, and which therefore constitute the archegonium. At the proper time one or more antherozoids force themselves through the neck of this archegonium, and presumably disappear in the interior of the central cell, *i.e.* in the *oosphere.* The *oosperm* or fertilised oosphere then becomes surrounded by a cell-wall (Fig. 450 III., *o*), divides into new cells, and gradually grows into a new plant (Fig. 450 IV.). In *Azolla* both kinds of sporangium contain a frothy mucilage, which, in the microsporangium, is collected into distinct lumps known as *massulæ*, each of which encloses a number of

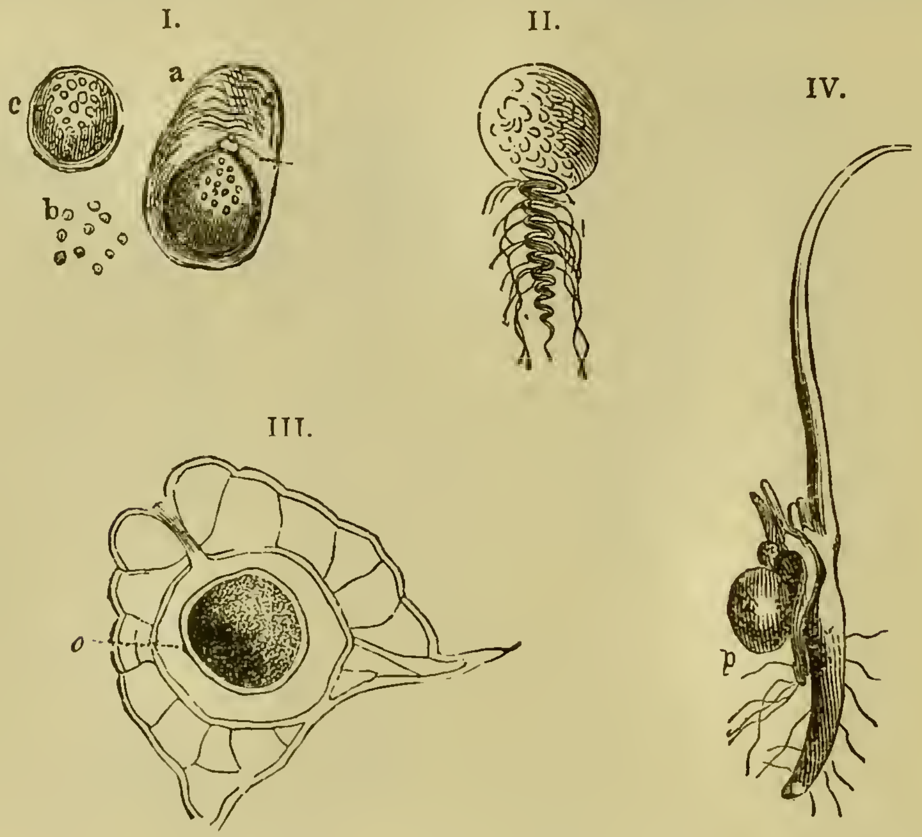


Fig. 450.—*Marsilea salvatrix*: I. *a* megaspore before fertilisation with its mucilaginous envelope; the prothallium is developed from the roundish papilla *p* at the apex of the spherical spore (× 15); *b* microspores (× 15); *c* single microspore (× 100); II. antherozoid with its attached vesicle (× 690); III. pro-embryo with oosperm seen in transverse section; the spherical oosperm *o* has already a cell-wall (× 200); IV. young plant seven days later, still attached to the spore *p* (× 7). (All after Hanstein.)

microspores. In their alternation of generations Rhizocarpeæ do not differ from the other classes of Vascular Cryptogams. *Salvinia* (Fig. 448) is absolutely rootless. On the older parts of the plant the leaves stand in whorls of three, the two upper leaves of the whorl being aërial leaves with entire margins, the lower one a submerged leaf divided into very narrow root-like segments.

There are only four genera of Rhizocarpeæ, which are classified, as follows, into two orders:—

1. *Marsileaceæ.* Perennial plants creeping in mud; the microsporangia and megasporangia are contained in the same sporocarp. The prothallium bears a single archegonium. The leaves are circinate in vernation: *Marsilea*, *Pilularia*.

2. *Salviniaceæ.* Annual plants floating on water; the microsporangia and megasporangia are formed in different sporocarps. The prothallium bears several archegonia: *Salvinia*, *Azolla*.

The sporocarps of several Australian species of *Marsilea* (Fig. 449) are known as 'nardoo,' and are used by the natives as an article of food.

CLASS XI. *Selaginellales.*

The plants belonging to this class present considerable diversities in relation to their vegetative organs. The Selaginellaceæ (Fig. 451 B) have usually a procumbent stem which branches dichotomously, but the branches develope only in one plane, so that the plant presents an external resemblance to the Jungermannieæ among the Hepaticæ. The leaves are simple, sessile, and with a single central vein; they are placed in four rows, and are of different sizes, the lateral rows consisting of larger, the upper and under rows of smaller leaves. A number of adventitious roots are produced on the under side of the stem facing the ground. The Isoëtaceæ (Fig. 452), consist mostly of aquatic plants with a simple cylindrical but only slightly developed stem and elongated grass-like leaves. The single genus belonging to this family, *Isoëtes*, is the only one at present known

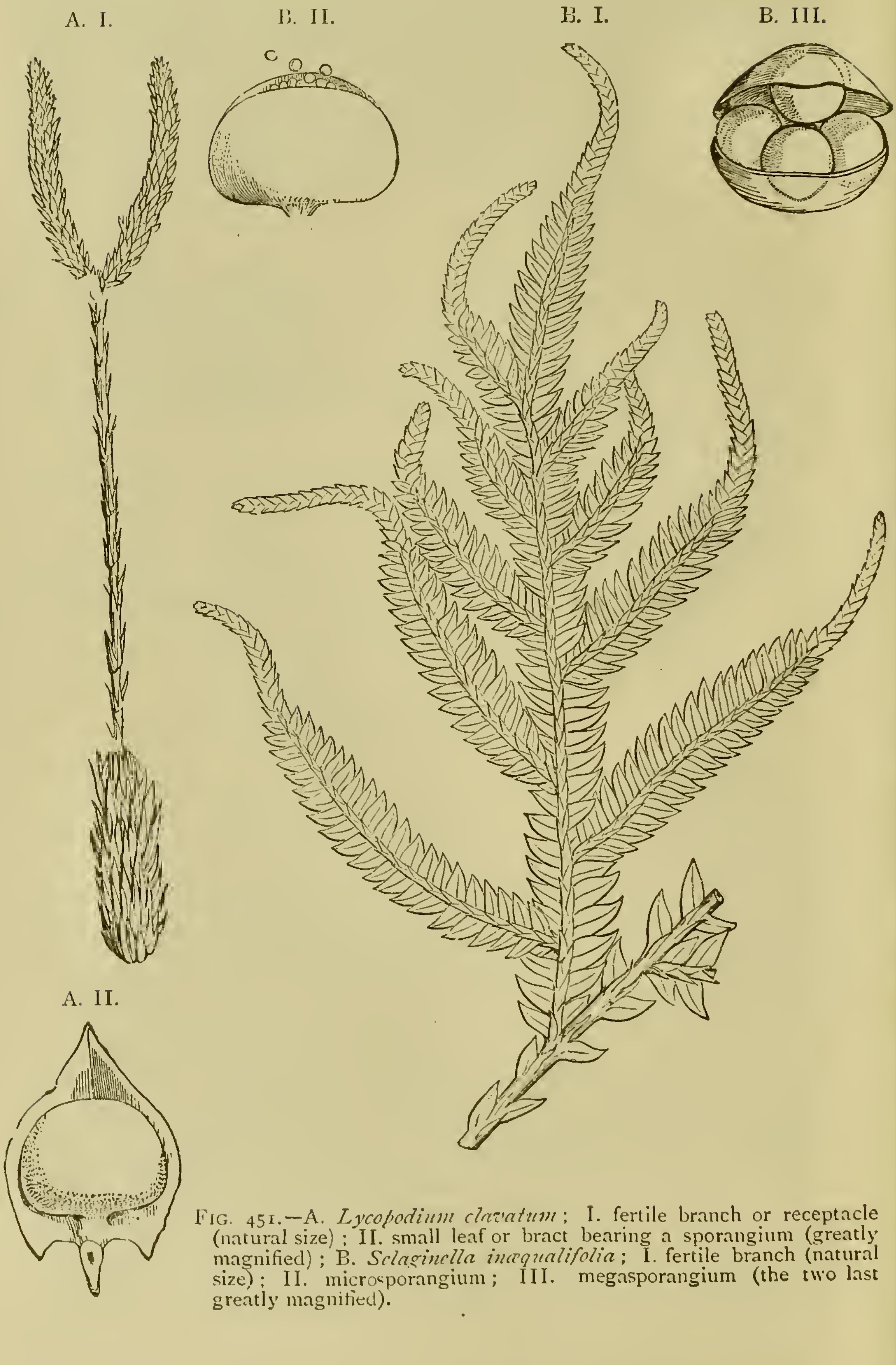

A. I.
B. II.
c
B. I.
B. III.
A. II.

FIG. 451.—A. *Lycopodium clavatum*; I. fertile branch or receptacle (natural size); II. small leaf or bract bearing a sporangium (greatly magnified); B. *Selaginella inæqualifolia*; I. fertile branch (natural size); II. microsporangium; III. megasporangium (the two last greatly magnified).

among Cryptogams in which the stem permanently increases in thickness; and this takes place by an annual formation of new masses of tissue round the central vascular bundle, the older ones gradually dying off on the outside. Since this process takes place almost entirely at two spots directly opposite to one another, the stem ultimately has the form of a plate or disc (Fig. 452 II.). The axis of the stem is occupied in all plants of this class by one or several closed vascular bundles separated from one another by intermediate parenchymatous fundamental tissue. In the Selaginellaceæ the vascular bundle is connected with the cortex by a very loose spongy tissue, so that it appears to lie almost isolated in a cylinder filled with air and connected with the walls only here and there by parenchymatous cells. The structure of the vascular bundle itself is always uniform. The xylem-portion consists of wider vascular cells in its inner, of narrower vascular cells in its outer part; the phloëm-portion possesses vessels, bast-fibres, and parenchymatous tissue. The axial vascular bundle sends out ramifications into the branches and leaves.

The fructification consists of sporangia or capsules which burst open when ripe, seated beneath a *ligule* at the base of the leaves; in *Isoëtes* in a *fovea* or pit. These sporangia are of two kinds (Fig. 451 B, II., III.): *megasporangia*, in which are formed four large *megaspores*; and *microsporangia*, in which a greater number of much smaller spores, the *microspores*, are developed. The microspores are themselves the antheridia, and break up into a small number of cells, one of which remains unproductive and may be regarded as an abortive prothallium, while antherozoids are developed in the remainder. The megaspores, on the other hand, as in the Rhizocarpeæ, produce a transitory prothallium, which bears archegonia opening outwardly (Fig. 452, I., IV.), and in their interior a central cell with its oosphere. In the Isoëtaceæ the prothallium entirely fills up the megaspore; while in the Selaginellaceæ it is attached to its apex as a

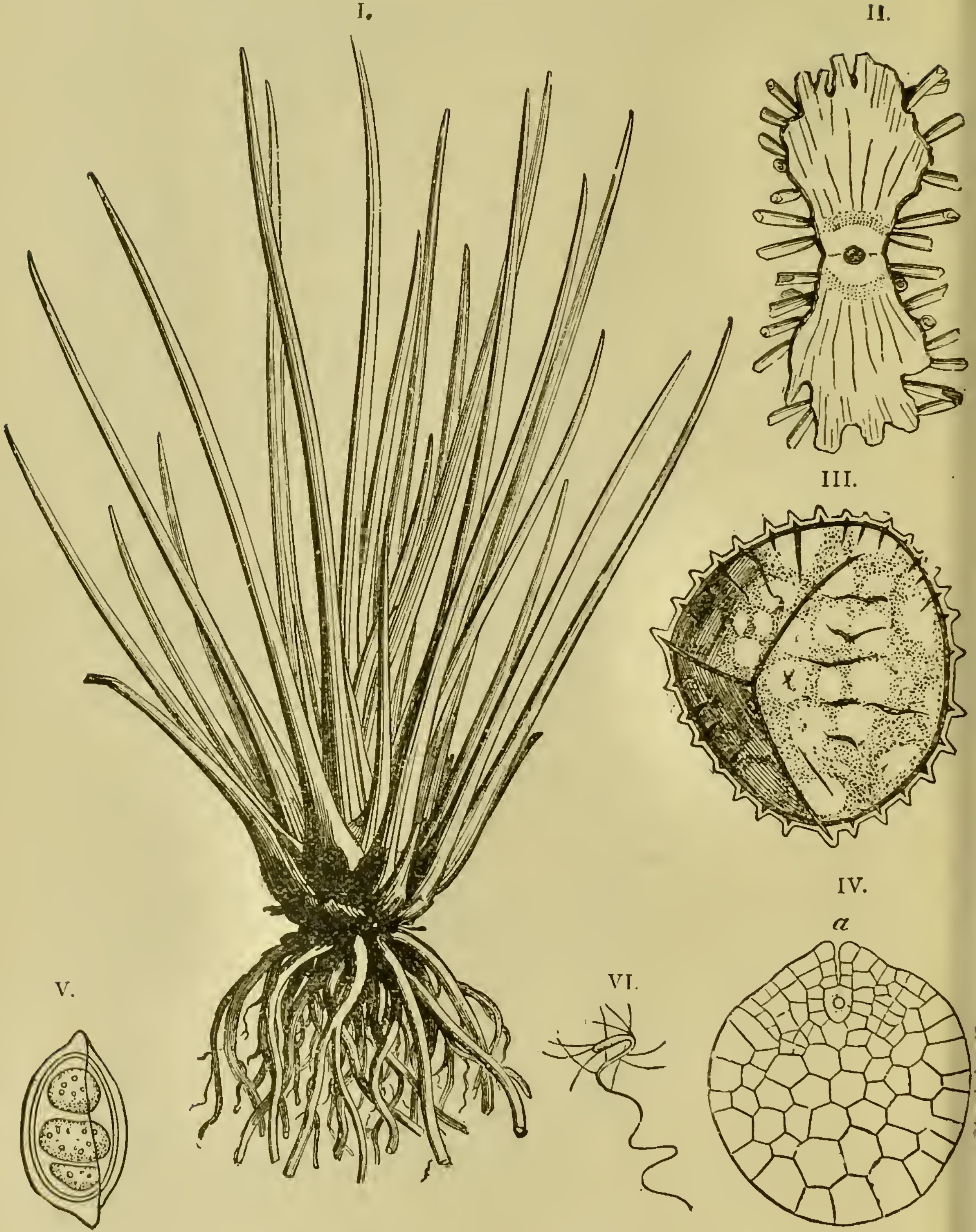


FIG. 452 —*Isoëtes lacustris* ; I. the whole plant (natural size) ; II. transverse section through the peculiarly thickened stem (natural size) ; III. megaspore (× 60) ; IV. longitudinal section through the prothallium with an archegonium *a* (× 40) ; V. microspore with three mother-cells of antherozoids (× 500) ; VI. antherozoid (× 500).

cap-shaped appendage. After fertilisation the embryo is, in *Isoëtes*, developed directly from the oosperm, while, in *Selaginella*, the latter forms at first a filiform *pro-embryo* or *suspensor*, on which the young plant is then developed. The process of alternation of generations resembles therefore that which prevails in other Vascular Cryptogams. The Selaginellales are also propagated in a non-sexual vegetative manner by means of *gemmæ*, that is, by buds formed in the axils of the leaves, which become detached from the parent-plant and develope into new individuals.

[The Selaginellales are divided into two families, as under :

1. *Selaginellaceæ.* Terrestrial plants with small leaves of two different sizes, often cultivated for their elegance : *Selaginella.*

2. *Isoëtaceæ.* Aquatic or rarely terrestrial plants with long grass-like leaves : *Isoëtes.*]

They are of no known economic value. [On fossil forms, see p. 325].

FLOWERING PLANTS.

CLASS XII. *Gymnospermæ.*

[The main characteristic of Gymnosperms, as distinguished from the other classes of Flowering Plants, is the absence of an ovary, the ovules being *gymnospermous*, entirely naked, and unprotected even by a perianth ; and the flowers are always unisexual. With this is necessarily connected a difference in the mode of fertilisation, which has already been explained (p. 191). In their reproductive organs, therefore, the Gymnosperms exhibit a decidedly lower type of organisation than Monocotyledons or Dicotyledons, and in many respects occupy an intermediate position between these classes and Cryptogams. The pollen-grains suggest a homology with the microspores of *Selaginella*, the nucellus with the megasporangium, and the corpuscules or secondary embryo-sacs with the central cell of the archegonium in the Heterosporous Vascular Cryptogams. The male flowers consist of a prolonged axis, on which are inserted a number of stamens, each consisting of a scale bearing on its under side two pollen-sacs. In the female flowers the ovules are sometimes borne directly on the axis, sometimes on the under side of scales, which are regarded by some as bracts, by others as open carpels. The ovule has only one integument, and the ripe seed always contains endosperm. In the anatomical structure of the wood Gymnosperms resemble Dicotyledons in all essential particulars (see also pp. 371–373, Figs. 478, 479).] The class is divided into three orders :—

Order 1. CYCADEÆ. The Cycadeæ (Fig. 453) are all tropical trees with simple stems, resembling Palms in their habit and Ferns in the mode of development of their leaves. Their columnar stems attain a considerable diameter, are tuberous or globular when young, and often even at a later period, and bear two kinds of leaves : the one dry, brown, hairy, sessile scales of a coriaceous texture and comparatively small size, the other large, stalked, simply pinnate foliage-leaves. They are diœcious. Both kinds of flowers are always placed in terminal cones at the apex of the stem, in the centre of the crown of leaves, and have no floral envelope or perianth, but consist simply of an axis, which is in the one case densely covered with peltate stamens, in the other bears the ovules. The two cotyledons are unlike in form, are connate with one another at their apex, and remain, on germination, enclosed in the albuminous seed. The pith of some species, as the East Indian *Cycas circinalis*, and the South African *Encephalartos lanuginosus*, afford a kind of sago. [Principal genera: *Cycas*, *Stangeria*, *Dïöon*, *Encephalartos*, *Zamia*.]

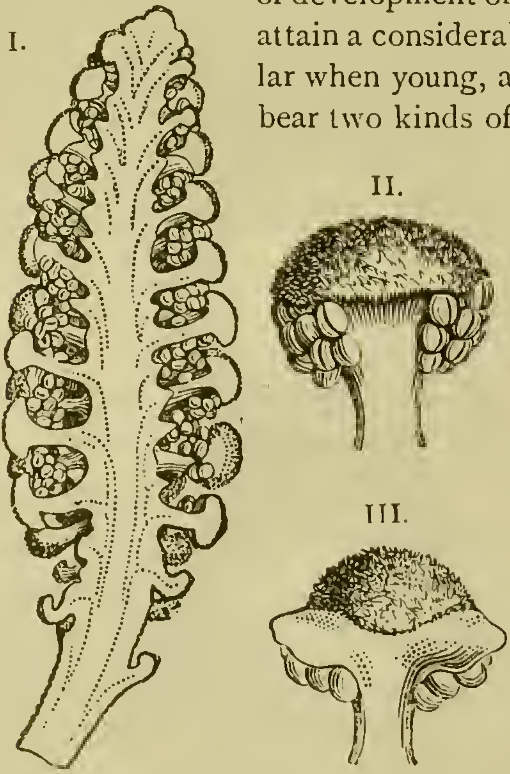


FIG. 453.—*Zamia* : I. male catkin in vertical section ; II. antheriferous scale, anterior face ; III. antheriferous scale, posterior face.

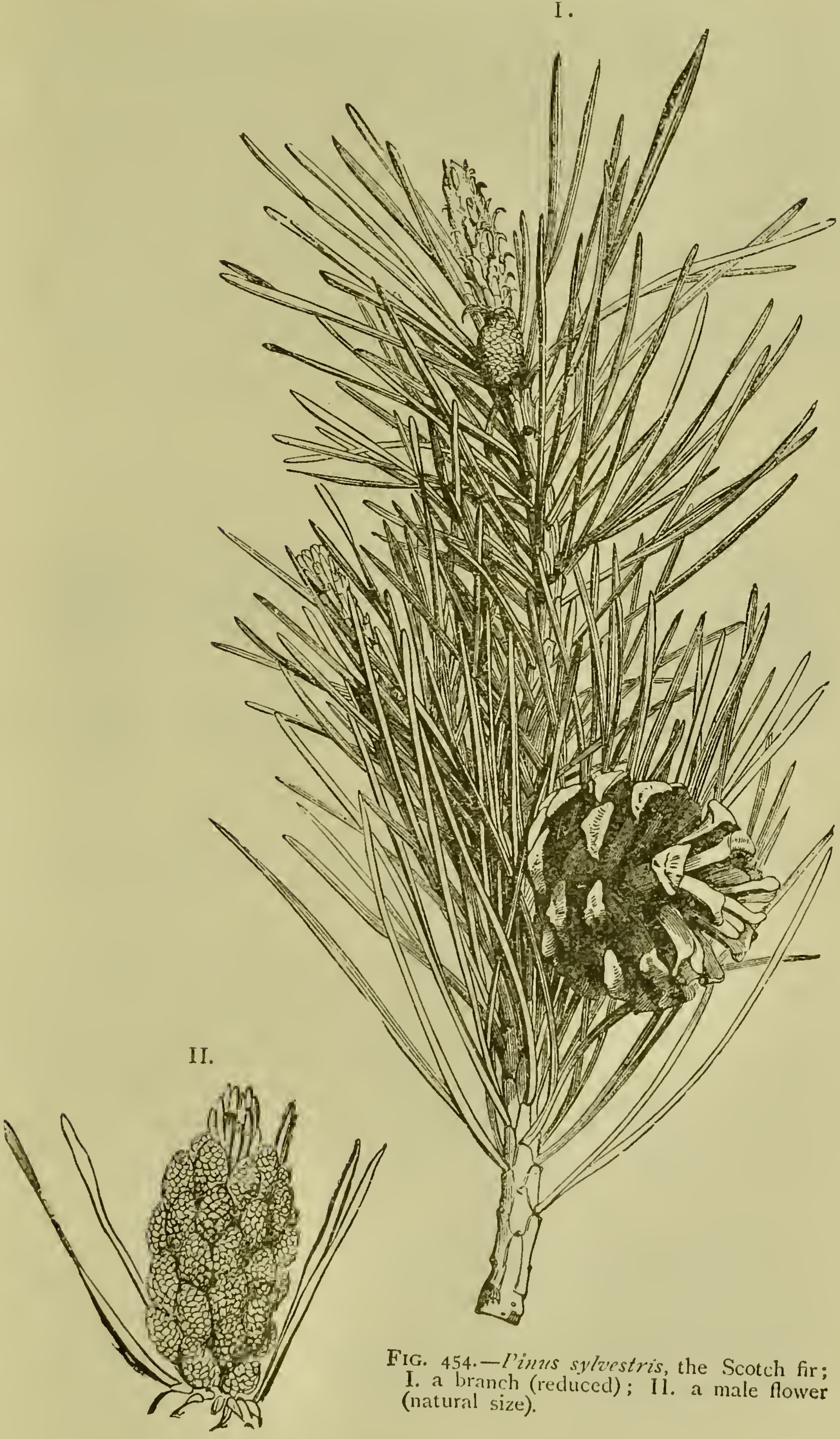


FIG. 454.—*Pinus sylvestris*, the Scotch fir; I. a branch (reduced); II. a male flower (natural size).

Order 2. CONIFERÆ. Trees or shrubs, with stems growing at their apex for not unfrequently several centuries, and attaining a height of 200 to 350 feet or more. Either all the leaves have the form of foliage-leaves, as in *Juniperus* and *Thuja*, or foliage-leaves alternate with membranous scales which serve to protect the buds, as in the Abietineæ. The leaves are small, usually acicular (Fig. 454), and persistent through the winter, in some cases enduring for several years. [The stem increases, as in Dicotyledons, by a ring of cambium ; but the secondary wood contains no true vessels, consisting entirely of tracheïds or wood-cells, the walls of which bear peculiar bordered pits (see Fig. 27, p. 18).] The flowers are always incomplete (without perianth), and either monœcious, as in *Abies*, or diœcious, as in the yew and juniper. The male flowers, which are often incorrectly called catkins, consist of stamens borne on an elongated axis, each bearing two or more pollen-sacs on its under side. The female flowers are of various forms, and are either solitary or united into peculiar cone-like inflorescences. In some genera the seed takes two years to come to maturity. In the *Cupressineæ* (Figs. 455, 456) the stamens are broad, and bear two or three pollen-sacs on a shield-like mid-rib. The ovules are erect and orthotropous, and stand in the axils of the bracts or carpellary scales. In some genera, as *Thuja* and *Cupressus*, the fruit is a cone ; in others, as *Juniperus*, it is berry-like, and formed by the coalescence and softening of several female flowers. The embryo has two or three cotyledons, which remain in the ground on germination. The fruit of the juniper, *Juniperus communis*, is officinal, and is applied to many purposes ; as also are the

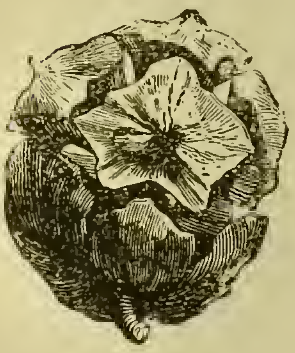


FIG. 455.—Ripe cone of *Cupressus* (natural size).

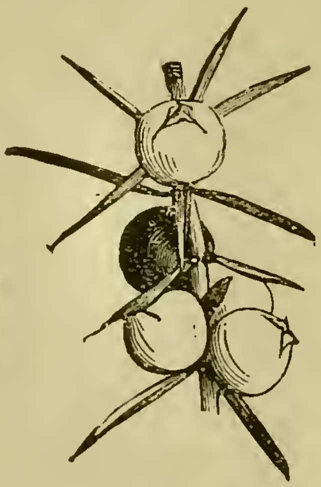


FIG. 456. — Berry-like fruit of the juniper (natural size).

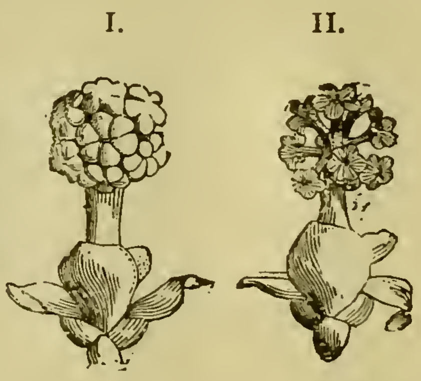
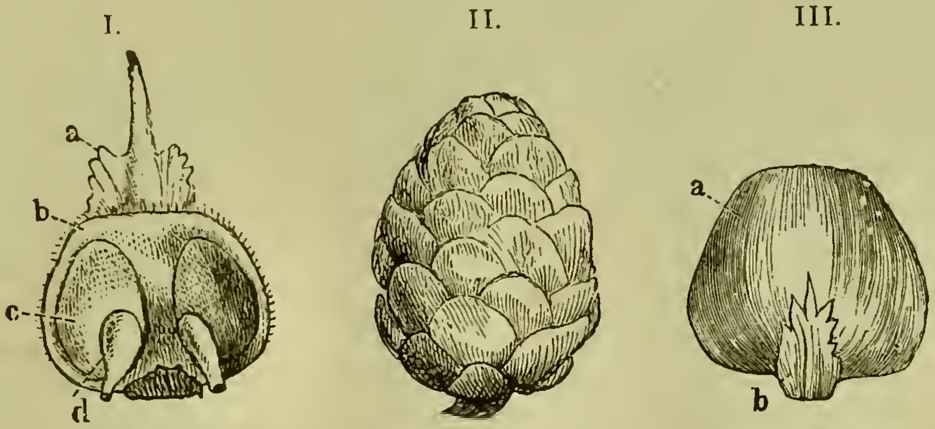


FIG. 457. — Male flower of the yew : I. before, II. after the discharge of the pollen (magnified).

young branches of the poisonous savine, *Juniperus Sabina*, and the resin from the North African *Callitris quadrivalvis*. The anthers of the *Taxineæ* (Fig. 457) are 2–8-lobed. The erect ovules (see Fig. 328, p. 154), which are either solitary or arranged in groups on a special branch, and either terminal or lateral, develope into nut-like seeds surrounded by a more or less thickened and fleshy envelope or aril. The embryo has two cotyledons which in some genera rise above the ground, while in others they do not. The poisonous leaves of the yew, *Taxus baccata*, are officinal. The *Abietineæ* (Figs. 454, p. 335; 458, 459) approach the Taxineæ in their two-lobed anthers, and the Cupressineæ in their fruit, which is a cone; but differ from both these suborders in their anatropous ovules with the micropyle directed downwards, and in the number of their cotyledons, which varies from five to twelve [or rather from two to fifteen]. The cone is also constructed differently from that of the Cupressineæ, being composed of imbricate bracts and



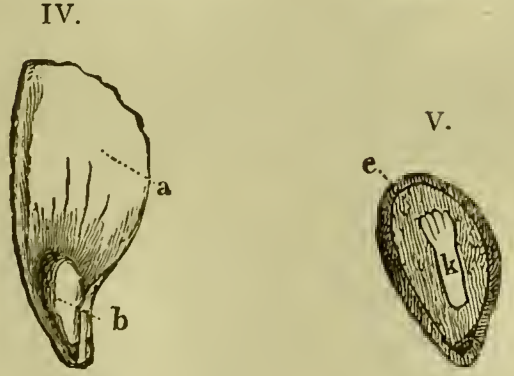


FIG. 458.—Larch (*Pinus Larix*); I. a seed-scale *b* from a young cone, seen from the inner side, with the bract *a*, and the two inverted naked ovules *d*; II. ripe cone; III. a scale *a* from a ripe cone, seen from the outer side, *b* the bract which has not grown along with the scale, and is therefore smaller; IV the seed *b* with its wing *a*; V. longitudinal section through the seed, the small embryo *k* lying in the endosperm *e*.

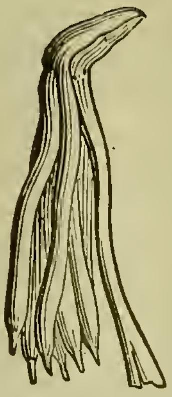


FIG. 459.—Anthers of *Araucaria*.

carpellary scales, each of which bears two winged ovules. These scales overtake in their growth the bracts which are situated between them, and which are arrested in their growth and become coriaceous or woody. The cedar of Lebanon, *Cedrus Libani*, is of historic interest, but has now nearly died out, and is related to the exotic Araucarieæ. The best-known European representatives of the sub-order are the Scotch fir, *Pinus sylvestris*, the Spruce fir, *Pinus excelsa*, the larch, *Larix europæa*, [and the stone pine, *Pinus Pinea.*] The various trees belonging to it are of the highest value for a great variety of purposes; the wood being employed for fuel and for building purposes, for joining and turning work, for the manufacture of musical instruments, &c. [and for the navy]. The wood of the root is lighter and is less used for fuel than that of the trunk, but is richer in resinous substances, and therefore more serviceable for the production of tar. *Pinus sylvestris*, *Pinea*, *nigricans*, and *Pinaster*, all yield common turpentine, from which turpentine-oil, pine-resin, colophony, and pitch are obtained. Venetian turpentine is prepared from the larch. *Abies balsamea* and *canadensis* of North America yield Canada-balsam; *Dammara orientalis* from the Moluccas, and *D. australis* from New Zealand, the Dammar resin or kauri-gum. *Pinites succinifer* is one of the extinct sources of amber. The starchy and oily seeds of *Pinus Pinea* and *P. Cembra* are edible. Many of the resins and volatile oils are officinal. [Principal genera:—*Araucaria*, *Dammara*, *Pinus*, *Larix*, *Cedrus*, *Picea*, *Abies*, *Sequoia*, *Cryptomeria*, *Taxodium*, *Frenela*, *Callitris*, *Libocedrus*, *Thuja*, *Biota*, *Cupressus*, *Juniperus*, *Taxus*, *Torreya*, *Phyllocladus*, *Salisburia*, *Cephalotaxus*.]

Order 3. GNETACEÆ. To this order belong only three genera, of remarkably different habit. The various species of *Ephedra* are shrubs destitute of foliage-leaves, with long slender cylindrical green-barked branches; at the joints of the stem are two opposite minute leaves, which grow together into a bidentate sheath, and from their axils spring the lateral branches. In *Gnetum* the leaves are also opposite on the jointed stem, but are stalked, and have a broad lanceolate lamina. *Welwitschia mirabilis*, the only representative of the third genus, never has more than two leaves, but these are of immense size.

CLASS XIII. *Monocotyledones.*

The embryo has only one cotyledon. The perianth is simple, or, when double, usually without distinction of colour, and the prevalent number of its parts is three or six. The leaves are most commonly parallel-veined.

The stem in its young state is always provided with an epidermis, the cells of which often contain silica, as in Grasses and Palms, giving the surface a vitreous appearance. The simple cortex consists of polygonal or roundish parenchymatous cells, among which are sometimes formed strongly thickened cubical sclerenchymatous cells, prosenchymatous cells, and bast-vessels. When very young the cortex is separated from the subjacent tissue by an annular layer of formative tissue, or cambium-sheath, in which the vascular bundles are formed, but the cambium possesses in general only a limited activity; and when this is exhausted, the stem no longer continues to increase in diameter at that spot; the cortical parenchyma then passes over gradually into fundamental tissue, or is separated from it by the lignified cambium-sheath (Fig. 460 I., V.). The vascular bundles stand singly in the fundamental tissue. The *cauline bundles*, or those which belong to the stem only, run parallel to the surface; by far the greater number, however, pass from the stem into the leaves; and these, termed the *leaf-traces*, at an early period cease to grow in a vertical direction, and turn towards the pith, bending outwards again from there to enter the leaves. When a number of bundles have been formed in this manner, every bundle which bends from the inner to the outer portion of the plant must cross all the younger ones in succession (Fig. 460 II.). The fibrovascular bundles are necessarily *closed*, in contrast to the open bundles of Dicotyledons and Gymnosperms. The term *Endogens* was previously applied to Monocotyledons, [and still is commonly in works on Descriptive Botany], because it was thought that the vascular bundles originated in the centre of the stem, and grew outwardly only in order to enter the leaves (see Fig. 95, p. 68).

In many species the course of the vascular bundles is essentially different from this, passing through the separate internodes in a parallel direction, while they bend irregularly

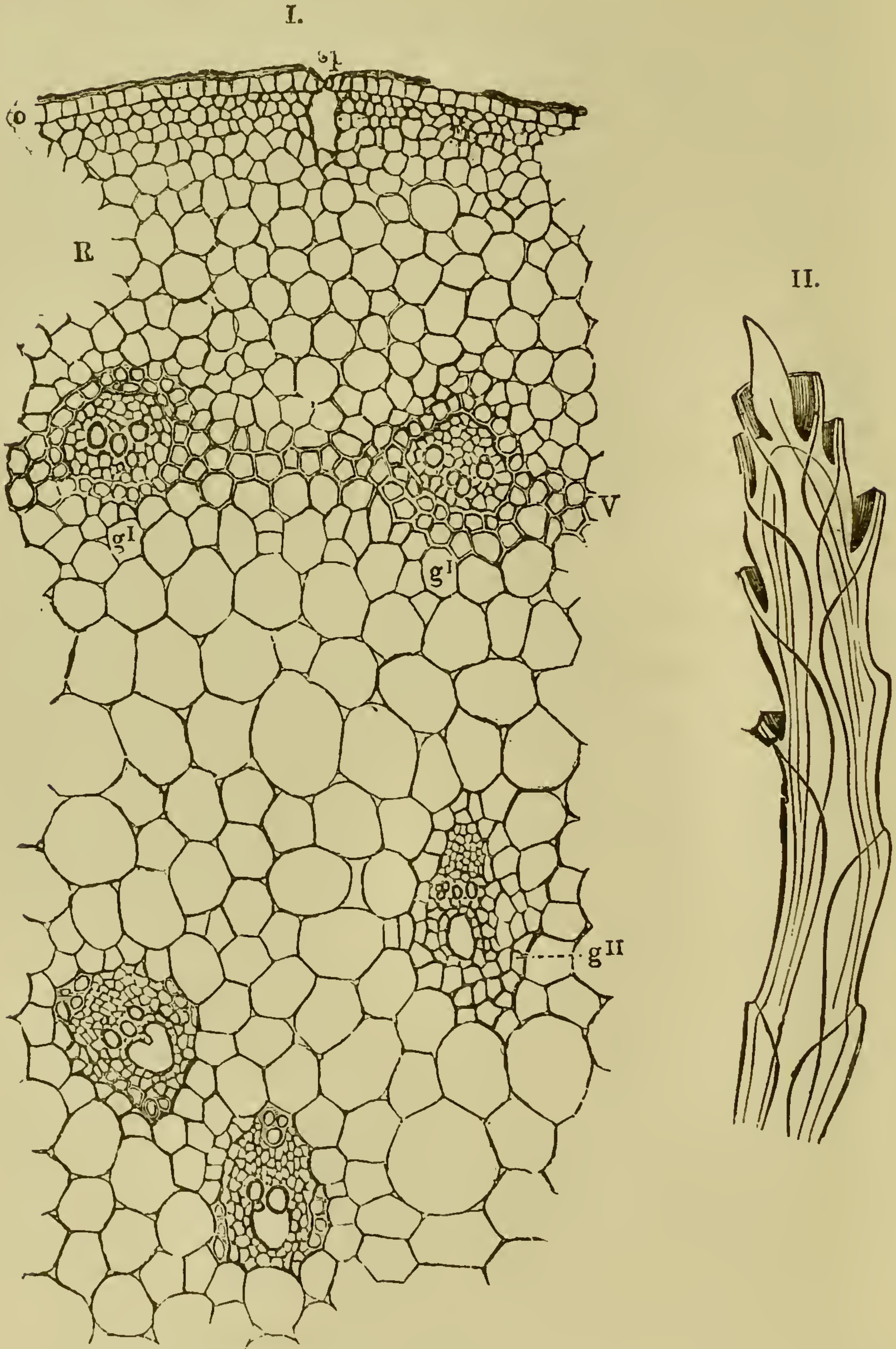


FIG. 460.—I. Part of a transverse section through the stem of *Tradescantia Selloï*; *o* epidermis, with a stoma *sp*; R cortex; V thickening-ring with the outer vascular bundles g'; g'' inner vascular bundles (× 75); II. course of the vascular bundles of *Iris* in longitudinal section (diagrammatic).

and branch in the nodes. This occurs, for example, in the culms of Grasses. The pith also disappears at a very early period in these cases, from rupture and desiccation, and probably also partly from resorption, so that the stem subsequently becomes hollow.

The separate vascular bundles are in general more highly developed than in the classes already described ; but their increase in thickness is limited, and soon ceases. The xylem-portion of the bundles may consist of wood-fibres, vessels, and parenchymatous cells ; the phloëm-portion of bast-fibres, sieve-tubes, and parenchymatous cells, with which are sometimes associated laticiferous vessels. The wood-fibres are sometimes more, sometimes less strongly thickened, but always lignified, and have a smaller number of scattered, slightly bordered, oval pits ; sometimes they are pointed at the ends, forming a prosenchymatous tissue, and resemble elongated parenchymatous cells. The bast-fibres are of similar structure, but, as a rule, more pointed. The vessels of the xylem-portion are annular, spiral, reticulated, or pitted. It is not uncommon also to find single vascular cells not united with others into true vessels. The lateral walls of the sieve-tubes are usually horizontal, and provided with sieve-discs ; the partition-walls, on the contrary, are mostly smooth, and only rarely, when united in growth with similar ones, also penetrated by sieve-pores, thus forming conducting sieve-cells. The parenchymatous cells, both of the xylem- and of the bast-portion, are usually elongated, and hence resemble prosenchymatous cells ; but always have horizontal partition-walls, and are either not at all lignified, or, at all events, less so than the wood-fibres. The laticiferous vessels are also sometimes found outside the vascular bundle ; and are then, when they contain raphides and belong to the cortex, called *utricular vessels* (see Fig. 75, p. 50). The arrangement of these separate elements of the vascular bundles of the stem is in general as follows (see Figs. 93, 94, pp. 65, 66). At their inner side next the pith is a bundle of wood-fibres, and in close contact with this are the vessels and vascular cells, which are partly surrounded by the parenchymatous cells of the xylem, partly intermingled with them. Then follows an easily distinguished thin-walled part consisting of sieve-tubes, conducting sieve-cells, and parenchymatous cells belonging to the phloëm-portion ; and finally, towards the cortex, a bundle of bast-fibres. Sometimes the bundles of fibres of the xylem and the phloëm coalesce laterally with one another by means of narrower or broader groups of wood-fibres, so as to form a closed ring surrounding the other elements of the vascular bundle.

The root of Monocotyledons has an epidermis provided with numerous root-hairs. The cortex is parenchymatous, and is often differentiated into an outer and an inner cortex. It is frequently separated from the inner portions by a sheath. The vascular bundle forms a closed hollow cylinder which encloses the central pith. The phloëm-cells, which are usually elliptical, lie between the radially placed vessels of the xylem. The xylem- and the phloëm-portions of the vascular bundle are separated by wood-fibres. The phloëm-portion consists of sieve-tubes lying within and of parenchyma pressed outwards.

The leaves are penetrated by fibrovascular bundles. When several enter a leaf, they may first unite into a leaf-stalk, or may be separated in their entire course, as occurs in many sessile leaves, like those of Grasses. The xylem-portion of the bundle faces the upper, the phloëm-portion the under side of the leaves. The skeleton of the leaf, formed of the vascular bundles, is surrounded by the parenchyma of the leaf. This parenchymatous portion or *mesophyll* separates—independently of the epidermis, which is always present and is provided with stomata and often with hairs—into two layers, the upper layer consisting of cylindrical, the under of rounder cells; the latter being, therefore, of a looser texture and often penetrated by wide air-passages.

[The following are the more important orders of Monocotyledons, arranged, with slight variation, according to Bentham and Hooker, those of less importance, and even one or two of the cohorts, being omitted:

DIVISION I. *Flowers glumaceous.*

Cohort I. GLUMALES. Flowers in the axils of scales (glumes), which are arranged in spikelets; perianth absent, or consisting of minute scales or hairs or bristles; stamens one to three, rarely more; ovary unilocular with one ovule; fruit a caryopsis; endosperm fleshy or floury; embryo immersed or not. Grasses or grass-like herbs.

Order I. GRAMINEÆ. Perianth absent, or of two, rarely three or six minute oblique scales; anthers versatile; fruit grooved on one side; embryo outside the endosperm on one side of its base; stem usually fistular, terete; leaf-sheaths split to the base.] Herbs, rarely, as in the bamboo, woody, shrubby plants; the cylindrical, usually hollow, stem, septated at the nodes, is called a *culm*. At the point of union of the divided leaf-sheath and the lamina—which is always entire and parallel-veined—is a membranous structure [of a stipular character], the *ligule* (Fig. 147, p. 92). The flowers are hermaphrodite, seldom monœcious, as in the maize, and are usually arranged in a panicle or spike, which, however, bears secondary spikes or spikelets instead of flowers. Each of these spikelets (Fig. 461) consists of a rachis, on which are placed the small inconspicuous flowers, concealed among closely crowded foliar structures. The two lowermost of the scale-like bodies usually have no flowers in their axis, and thus serve as a common envelope for the whole spikelet, and are termed *glumes*. The flowers, which are arranged in two rows, are solitary in the axils of the next scales; and since each flower has also at its base a special scale, it has two belonging to it, which are called *paleæ*, an exterior or inferior, and an interior or superior one. The inferior pale has a mid-rib, which is often prolonged at the apex into a bristle, projecting from the back of the pale, and is called an *awn* (Figs. 462, 463). The inner pale has no midrib, but often two lateral nerves, and is hence bidentate at the apex. Within the paleæ, and alternating with them, are two, rarely, as in the sugar-cane, three minute scales, the *lodicules*, which correspond to the perianth. The stamens are three, rarely two (in *Anthoxanthum*), or six (in the rice), the anthers being versatile at the end of long filaments (Fig. 270, p. 138). The ovary is superior, unilocular and with a single ovule, and usually bears two, less often (in *Nardus*) one, or (in the sugar-cane) three stigmas. The fruit has a dry pericarp, and is an indehiscent *caryopsis*, the seed adhering in its growth to the pericarp and often to the paleæ. The embryo is small, on the outside of a large floury endosperm, and is enveloped by the single large cotyledon,

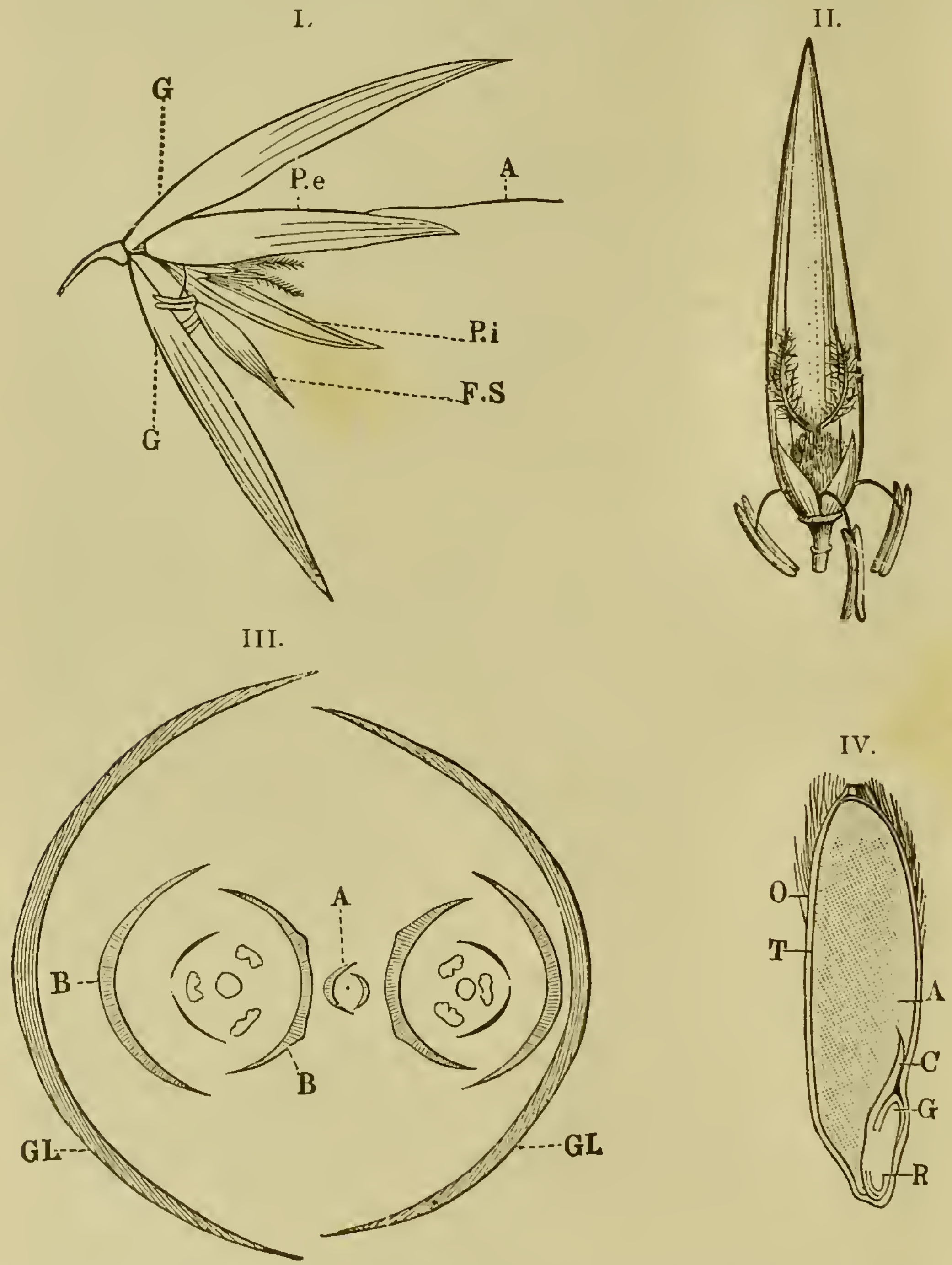


Fig. 461.—I. Expanded spikelet of the oat, with a fertile and a barren flower F S ; G glumes ; P*e* outer pale, with awn A ; P*i* inner pale ; within are the feathery stigmas ; II. fertile flower with the outer pale removed (all much magnified) ; III. diagram of a spikelet with two fertile and one barren flower A ; B paleæ ; G L glumes ; IV. longitudinal section of a seed ; A endosperm ; C the single cotyledon (scutellum) ; G plumule ; R radicle ; T testa ; O hairs (greatly magnified).

which is called the *scutellum* (Fig. 461, IV.); [though the scutellum is by some considered an outgrowth of the axis]. The Grasses constitute one of the largest orders in the vegetable kingdom, and are universally distributed, but form meadows only in the temperate zone. Many genera are cultivated for the sake of the nutriment contained in the seed, and form our cereal crops. Among these are wheat *Triticum vulgare*, spelt *T. spelta*, rye *Secale cereale*, barley *Hordeum vulgare*, *hexastichon*, and other species, various species of oat *Avena*, millet *Panicum miliaceum*, maize or Indian corn *Zea Mais*, rice *Oryza sativa*, and Egyptian millet *Sorghum vulgare*. The seeds of many species, especially wheat, contain gluten (protein) in addition to starch. Sugar occurs in the stem of most Grasses, but chiefly in the sugar-cane, *Saccharum officinarum*. Among officinal products are the rhizome of the couch-grass, *Triticum repens*. Among the more serviceable meadow-grasses are *Anthoxanthum odoratum*, *Alopecurus pratensis*, *Phleum pratense*, *Agrostis vulgaris*, *Holcus lanatus*, *Avena flavescens* and *pubescens*, *Briza media*, *Poa annua*, *trivialis*, and *pratensis*, *Dactylis glomerata*, *Cynosurus cristatus*, *Festuca ovina*, *pratensis*, *rubra*, and *elatior*, *Bromus mollis*, and *Lolium perenne*. The largest species is the East Indian bamboo, *Bambusa arundinacea* (Fig. 464), 30 to 60 feet high. [Important genera:—*Andropogon*, *Panicum*, *Digitaria*, *Setaria*; *Zizania*, *Oryza*, *Anthoxanthum*, *Phalaris*, *Zea*, *Coix*, *Phleum*, *Alopecurus*, *Agrostis*, *Milium*, *Macrochloa*, *Stipa*, *Calamagostis*, *Arundo*, *Phragmites*, *Ammophila*, *Cynodon*, *Spartina*, *Aira*, *Arrhenatherum*, *Avena*, *Holcus*, *Poa*, *Glyceria*, *Briza*, *Melica*, *Molinia*, *Dactylis*, *Cynosurus*, *Festuca*, *Bromus*, *Bambusa*, *Lolium*, *Triticum*, *Elymus*, *Nardus*, *Hordeum*, *Secale*, *Sorghum*, *Saccharum*.]

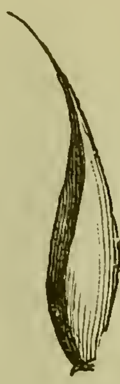


FIG. 462.—Seed of *Dactylis glomerata*, with terminal awn.

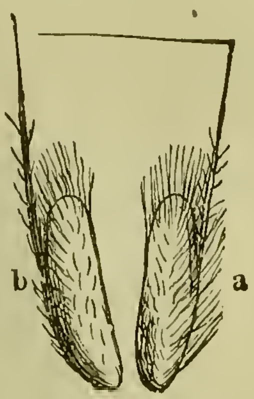


FIG. 463.—Outer paleæ of the two barren flowers of a spikelet of *Anthoxanthum*; *b* with a straight, *a* with a bent dorsal awn.

Order 2. CYPERACEÆ. Perianth absent or consisting of bristles, rarely scales, or of a sheathing bract; anthers basifixed; fruit compressed or trigonous; embryo at the base of endosperm; stem usually solid and triangular; leaf-sheaths entire. Perennial plants of grass-like habit, often with creeping underground tuberous rhizomes (Fig. 465). The aërial portion of the stem is, with the exception of the inflorescence, unbranched, unseptated, and usually triangular; the leaves are all radical, with a sheathing but not split base, and no ligule; the lamina is parallel-veined, and often three-edged. The flowers are arranged in spikes,

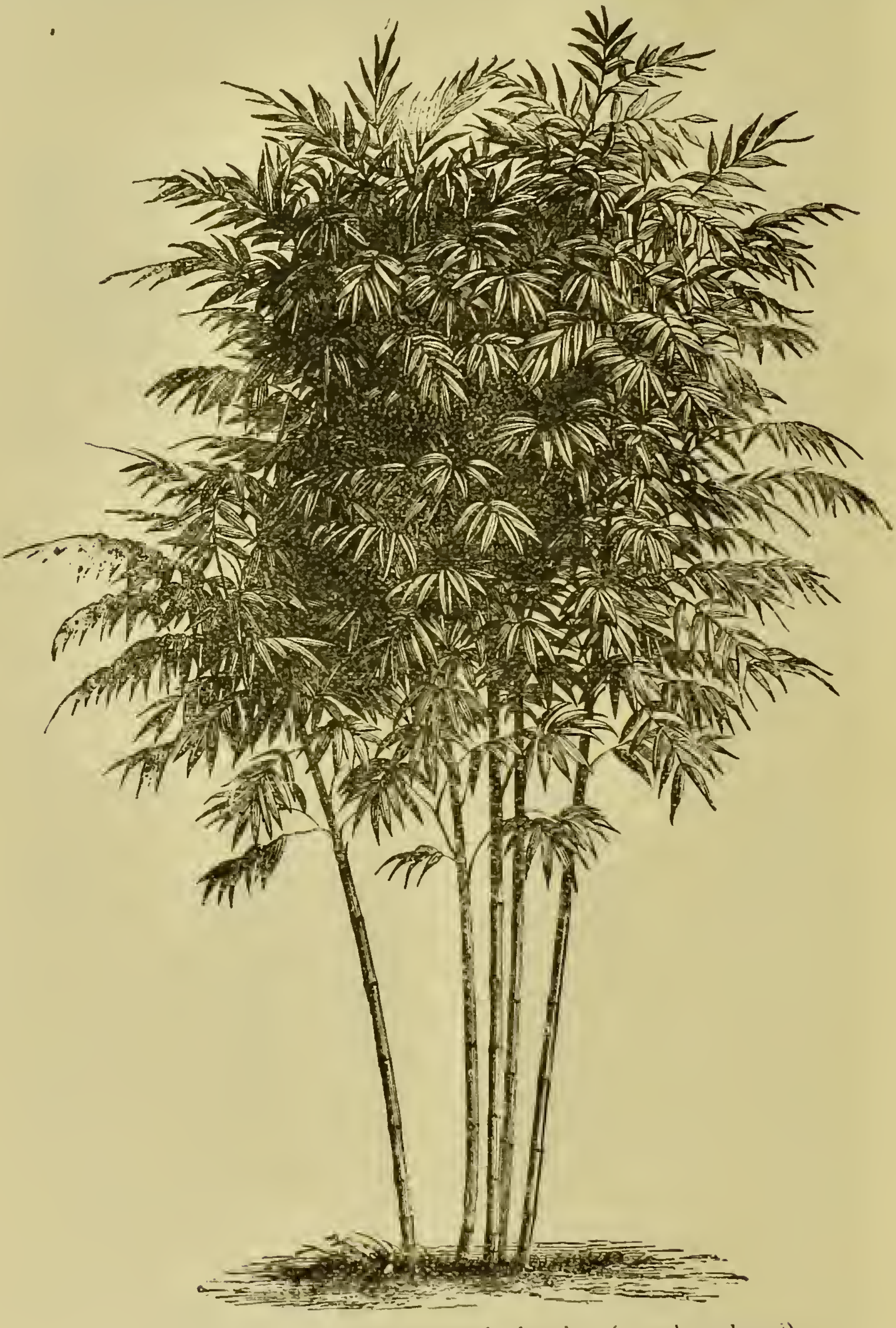


FIG. 464.—*Bambusa Thouarsii,* the bamboo (greatly reduced).

panicles, capitula, or cymes, and are either hermaphrodite or unisexual, and in the latter case usually, as in *Carex,* the male and female flowers are placed in different spikes on the same stem. Each flower stands in the axil of a bract, which is called a *glume* or *pale*, two of these pales usually occurring in each flower; and then the inner one is either adherent to the rachis, or, as in *Carex*, is transformed into a sheathing bag or *utricle* enclosing the flower. The genera with hermaphrodite flowers are either entirely destitute of a perianth, as *Cyperus* (Fig. 466) and *Cladium*, or it is composed of bristles, either few in number, as in *Scirpus* and *Rhynchospora*, or in large numbers, and in that case forming a tuft of hairs closely resembling cotton-wool springing from the inflorescence, as in the cotton-grass, *Eriophorum*. In *Carex* the male flower consists of three stamens, the female flower of a tubular envelope, the utricle, surrounding the free ovary, which is generally unilocular and one-seeded, but with three stigmas (Fig. 467). The fruit is a caryopsis; the small embryo is surrounded by the floury endosperm. The rhizome of many Cyperaceæ is rich in starch and gelatine; and that of *Cyperus esculentus* is used as an article

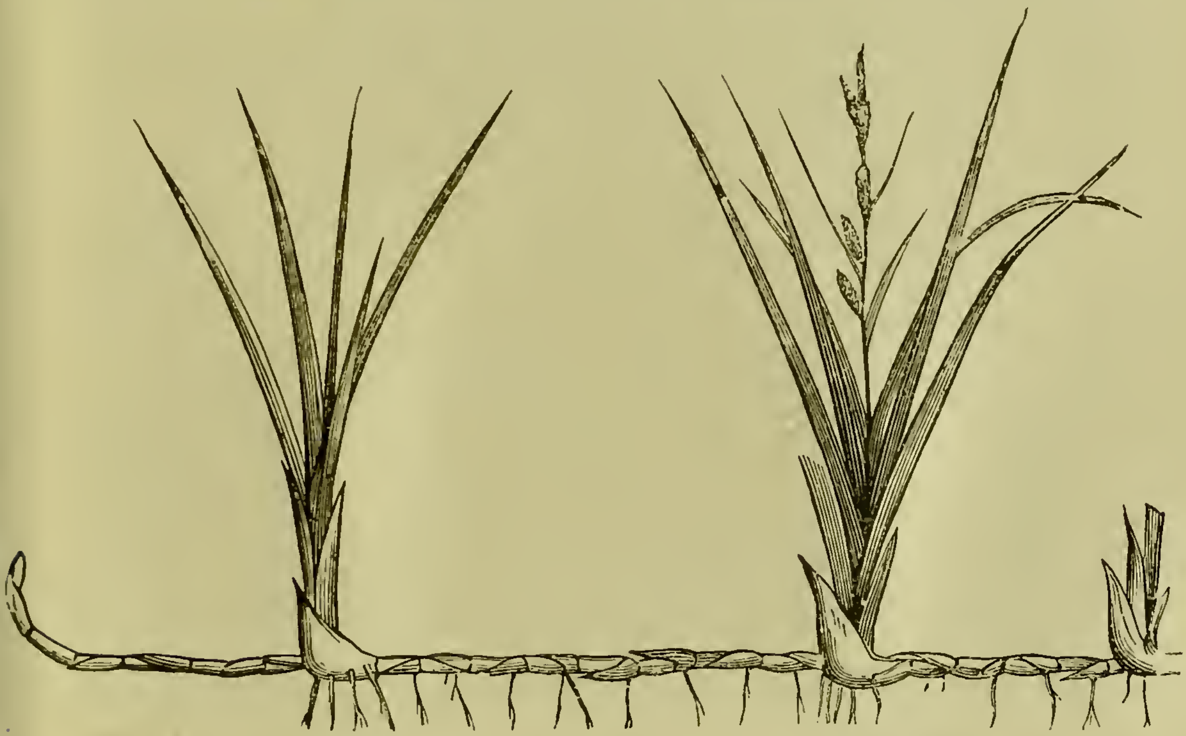


FIG. 465.—Creeping rhizome of *Carex* (greatly reduced).

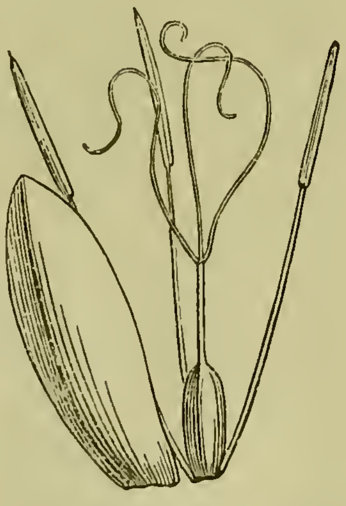


FIG. 466—Flower of *Cyperus longus* with the parts separated (magnified).

of food in the South of Europe; several species of *Carex* are officinal. *Papyrus antiquorum*, the papyrus of Egypt and Sicily, was the first material used as paper. [Principal genera:—*Papyrus*, *Cyperus*, *Eleocharis*, *Eriophorum*, *Scirpus*, *Isolepis*, *Schœnus*, *Cladium*, *Rhynchospora*, *Carex*.]

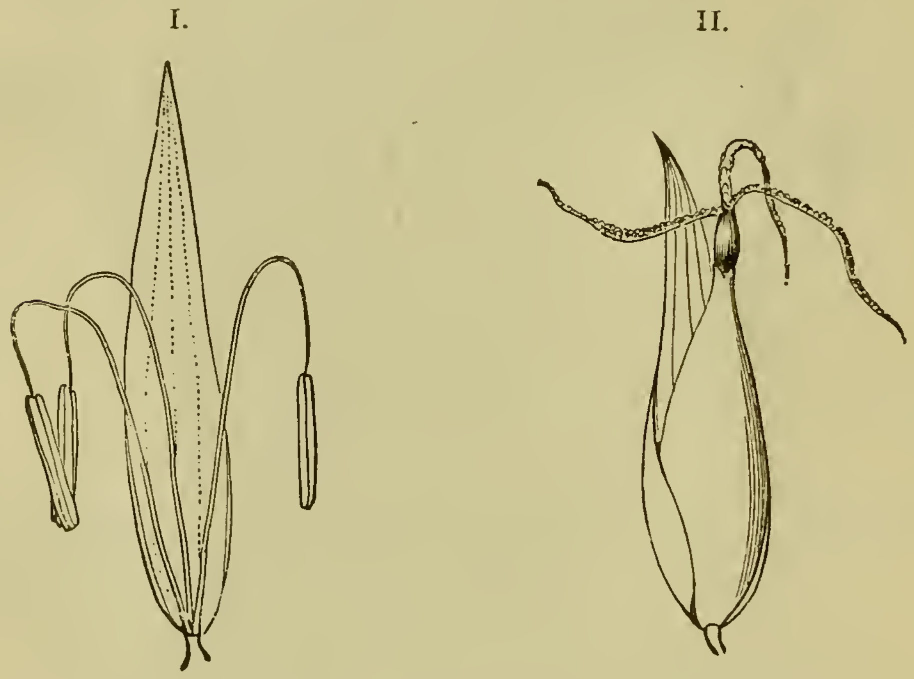


FIG. 467.—I. Male flower, II. female flower of *Carex* (magnified).

DIVISION II. *Flowers petaloid. Ovary inferior (with a few exceptions). Perianth usually distinct, in two rows, and coloured.*

[Cohort II. AMOMALES. Albumen (perisperm) floury; embryo distinct; flower usually hermaphrodite and very irregular; perianth of five or six segments; stamens six, one or five with anthers, the rest petaloid, or all with anthers in Bromeliaceæ; ovary usually trilocular; fruit a berry or capsule. Tropical plants with large stalked leaves with broad lamina, the lateral veins at right angles to the mid-rib. The cohort comprises the orders *Cannaceæ* (*Canna*, *Maranta*); *Zingiberaceæ* (*Zingiber*, *Amomum*, *Alpinia*); *Musaceæ* (*Musa*, *Strelitzia*); *Bromeliaceæ* (*Bromelia*, *Tillandsia*).

Cohort III. ORCHIDALES. Endosperm absent or cellular; embryo very obscure; flower hermaphrodite and very irregular; perianth of six, rarely three, segments; stamens one, two, or three, confluent with the style (gynandrous); fruit a capsule.

Order 1. ORCHIDEÆ. Stamens one or two, confluent with the style and stigma; ovary unilocular, rarely trilocular; seeds very minute.] Our native orchids have a tuberous root (Figs. 119, 120; p. 81), and an annual herbaceous stem. The tropical species, on the contrary, have often a perennial, and some of them a climbing stem, or peculiar aërial *pseudo-bulbs*. The amplexicaul or sheathing leaves are always entire, usually lanceolate, fleshy or succulent, rarely scale-like. The flowers are rarely solitary, usually in spikes, racemes, or panicles; and the superior perianth consists of two whorls, each of three leaves. Of these the inner whorl is always irregular, and often has a spurred lip or *labellum*, the remaining five leaves of the perianth forming together the *galea* or helmet. The stamens are united with the style into a fleshy column or *gynostegium*, upon which the anthers are so placed as to stand above the stigma, which is but little developed, and consists usually of a large viscid surface. Of the six stamens which are probably originally present, only one, less often two, attain perfect development. When only one is thus developed, it is always opposite the labellum ; but when two, then one is on each side of the gynostegium. Only a few Orchids have the pollen-grains perfectly distinct ; usually they are united together in fours, and these again into granular masses ; or the grains are combined by a viscid fluid into a club-shaped mass or *pollinium* within each anther-lobe (Fig. 468, v.). The two pollinia terminate at their lower end in a pedicel consisting of the dried-up viscid substance, connected together by a viscid gland or *rostellum* as in the bee-orchis, or distinct as in *Orchis Morio.* Sometimes the rostellum is concealed in a fold of the stigma. The fruit is a capsule, usually dehiscing longitudinally. The numerous very small exalbuminous seeds are usually covered with a reticulated testa, and do not contain any trace of a cotyledon. In the tubers are mucilage and starch ; *Orchis Morio*, *mascula*, *militaris*, and other species, yield salep. The fruits of some species are rich in aromatic substances; the officinal vanilla is obtained from *Vanilla aromatica*, *planifolia*, and perhaps some other species from tropical America. [Principal genera :—*Dendrobium*, *Masdevallia*, *Malaxis*, *Bolbophyllum*, *Cattleya*, *Epidendrum*, *Odontoglossum*, *Maxillaria*, *Vanda*, *Saccolabium*, *Stanhopea*, *Oncidium*, *Lycaste*, *Angræcum*, *Catasetum*, *Orchis*, *Serapias*, *Aceras*, *Satyrium*, *Ophrys*, *Platanthera*, *Gymnadenia*, *Habenaria*, *Limodorum*, *Corysanthes*. *Vanilla*, *Listerà*, *Neottia*, *Epipactis*, *Spiranthes*, *Cypripedium*.]

[Cohort IV. NARCISSALES. Flowers hermaphrodite, regular or irregular; perianth usually petaloid ; stamens three or six, inserted on the perianth-tube : ovary trilocular; seeds with copious fleshy or horny endosperm, and a distinct embryo ; leaves parallel-veined. Principal orders :—*Irideæ* (*Gladiolus*, *Iris*, *Crocus*, *Tigridia*) ; *Amaryllideæ* (*Galanthus*, *Narcissus*, *Crinum*, *Pancratium*, *Amaryllis*, *Leucojum*, *Agave*).

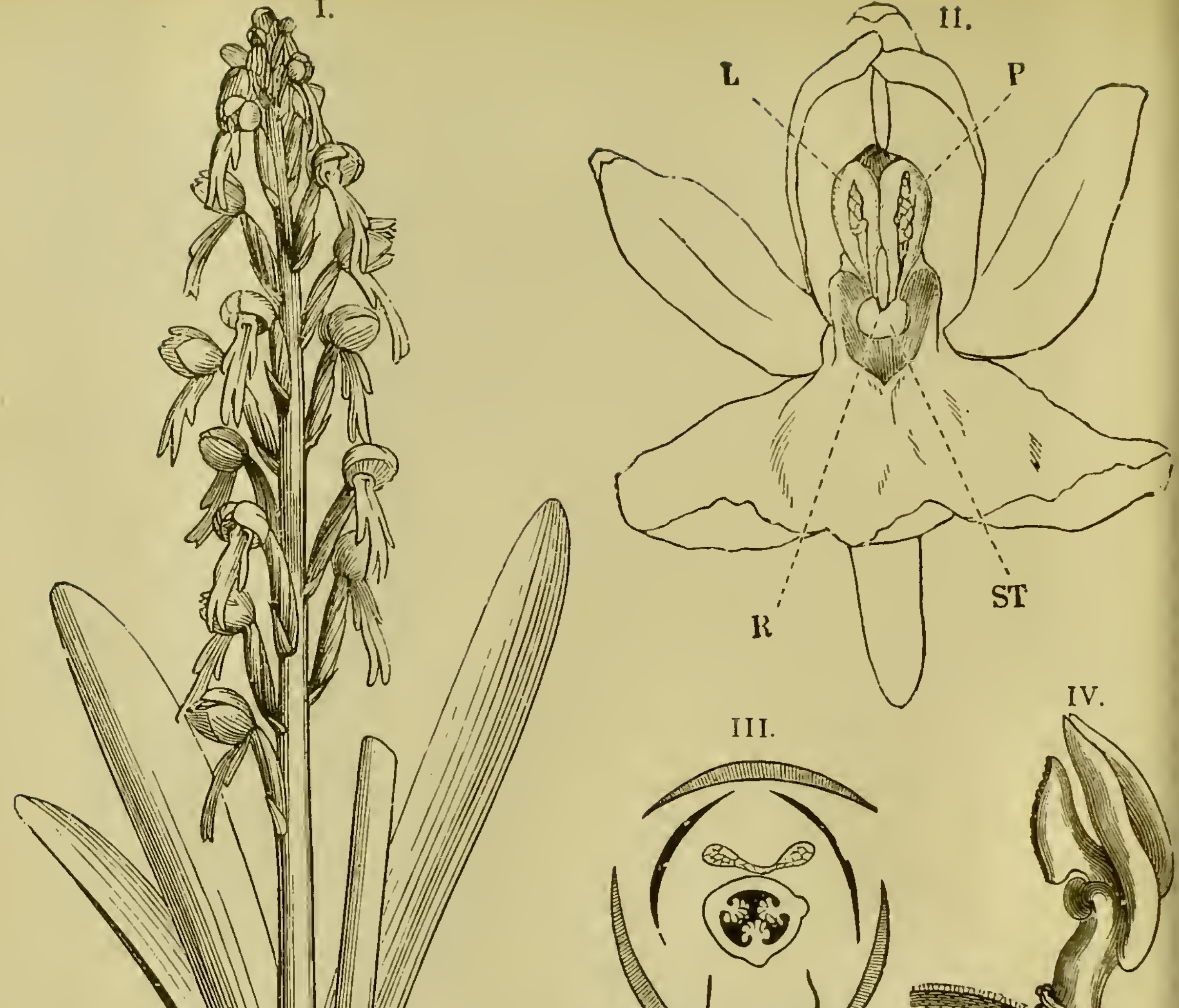


FIG. 468.—I. *Aceras anthropophora*, man orchis ; whole plant (natural size) : II. flower of an orchid looked at in front, the ovary being concealed ; L P anther lobes, each containing a pollinium ; ST stigma ; R rostellum (magnified) : III. diagram of the flower of an orchid ; IV. gynostegium of *Cypripedium*, seen laterally ; above to the right the anther, to the left the stigma (magnified) ; V. pollinia of an orchid with their pedicels, united by the rostellum (greatly magnified) ; VI. burst capsule (natural size) ; VII. transverse section of an ovary (magnified).

Cohort V. DIOSCORALES. Flowers diœcious, regular; perianth herbaceous; stamens six, inserted at the base of the perianth-segments; ovary trilocular; fruit a berry or capsule; seeds with copious fleshy endosperm, and a distinct included embryo. Climbing herbs or small shrubs, with netted-veined leaves. Order *Dioscoreaceæ* (*Dioscorea*, *Tamus*, *Testudinaria*).

DIVISION III. *Flowers petaloid. Ovary superior.*

Cohort VI. POTAMALES. Ovary apocarpous (rarely reduced to one carpel); flowers hermaphrodite or unisexual; perianth of three, four, or six segments, or absent; stamens one to six; seeds exalbuminous; embryo conspicuous. Usually water-plants. Principal orders:— *Butomaceæ* (*Butomus*); *Alismaceæ* (*Alisma*, *Sagittaria*); *Potameæ* (*Potamogeton*); *Naiadeæ* (*Zostera*, *Naias*).

Cohort VII. PALMALES. Ovary syncarpous (rarely apocarpous); flowers unisexual, arranged on a simple or branched spadix, enclosed in a spathe or not; perianth of distinct bi-seriate coriaceous segments, green, rarely coloured or absent; fruit a one- rarely two-seeded drupe or berry; seed albuminous. Shrubs or trees with flabellate or pinnately divided, rarely simple leaves.

Order I. PALMÆ. Flowers usually diclinous on a branched spadix; perianth green; stamens usually six, hypogynous or perigynous; ovary tri- rarely uni-locular, or of three separate carpels; styles short, free or connate; loculi with one, rarely two, ovules; seed large; embryo minute, sunk in a pit of the fleshy or horny endosperm. Trees or shrubs.] Although the Palms appear to belong to the more highly developed Monocotyledons from their stately arborescent stems and their large leaves, the insignificance of their flowers reminds one of the lower families, and the habit of many species even of the Grasses; while the structure of the flower and inflorescence allies them to the Arales (Figs. 469, 470, 471). The stem is usually simple, rarely dichotomously branched, as in the doom-palm, generally erect, sometimes climbing, as in the rattan, and commonly bears a crown of leaves only at its summit. The leaves, often called fronds, are fan-shaped in the fan-palms, pinnate in the feather-palms, rarely undivided. The flowers are placed on a simple or branched rachis, which is surrounded in vernation by a common envelope or *spathe*; they are originally perfect, but almost always become, in the course of development, diclinous or polygamous from the abortion of stamens or pistils. The six perianth-

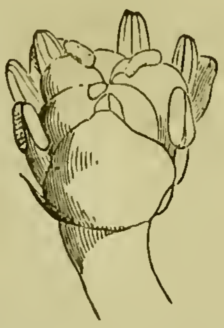


FIG. 469.—Flower of the European dwarf-palm, *Chamærops humilis*.

leaves are in two whorls. The stamens, three, six, or more in number, are adherent to the perianth-segments. The superior ovary is either uni-

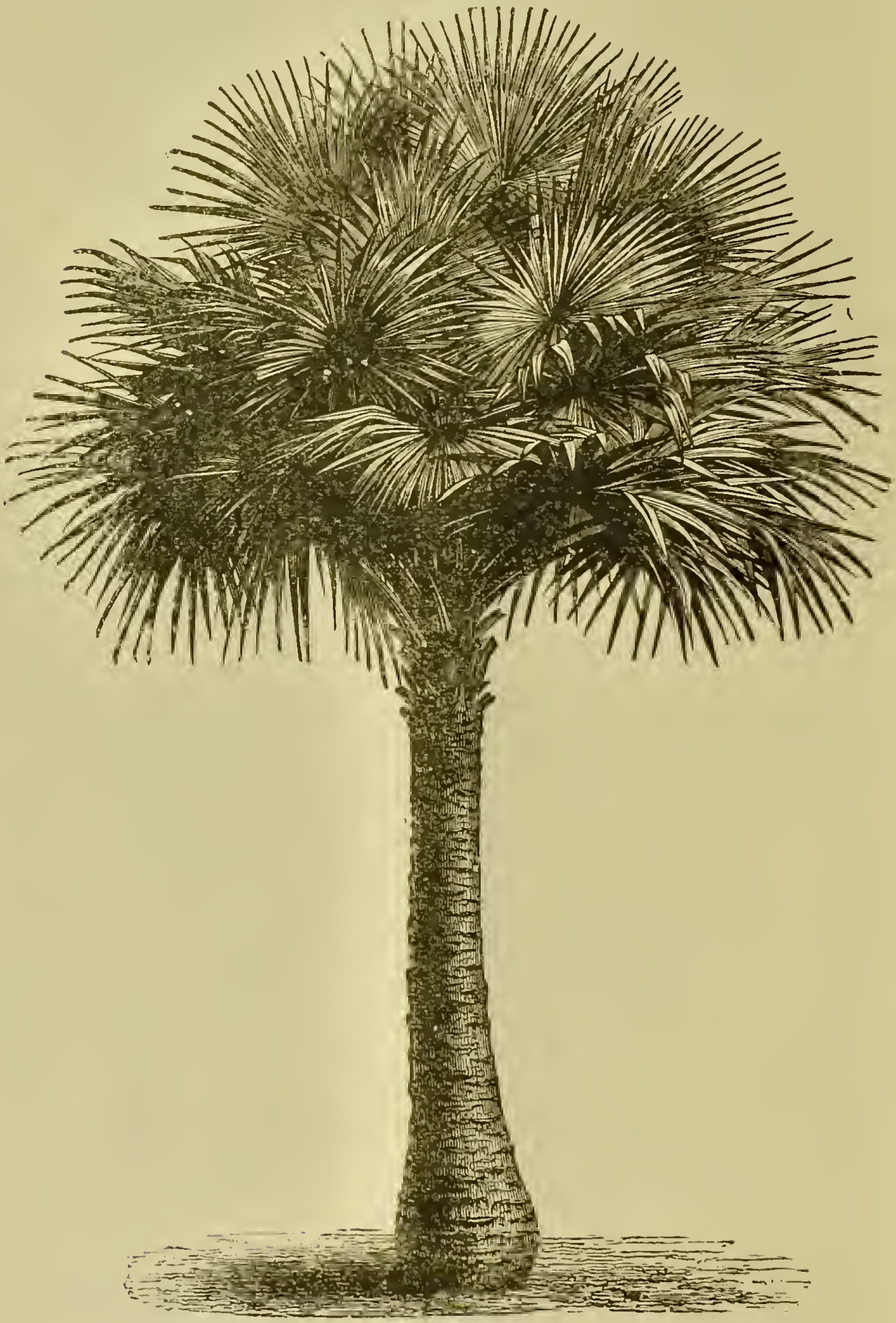


FIG. 470.—*Livistonia australis,* a fan-palm (greatly reduced).

locular, consisting of three united carpels, or trilocular and apocarpous. Each of the three loculi contains a single ovule, which is generally erect and orthotropous; but two of the ovules usually disappear before maturing into seeds. The fruit is a one- or three-seeded drupe or berry, the

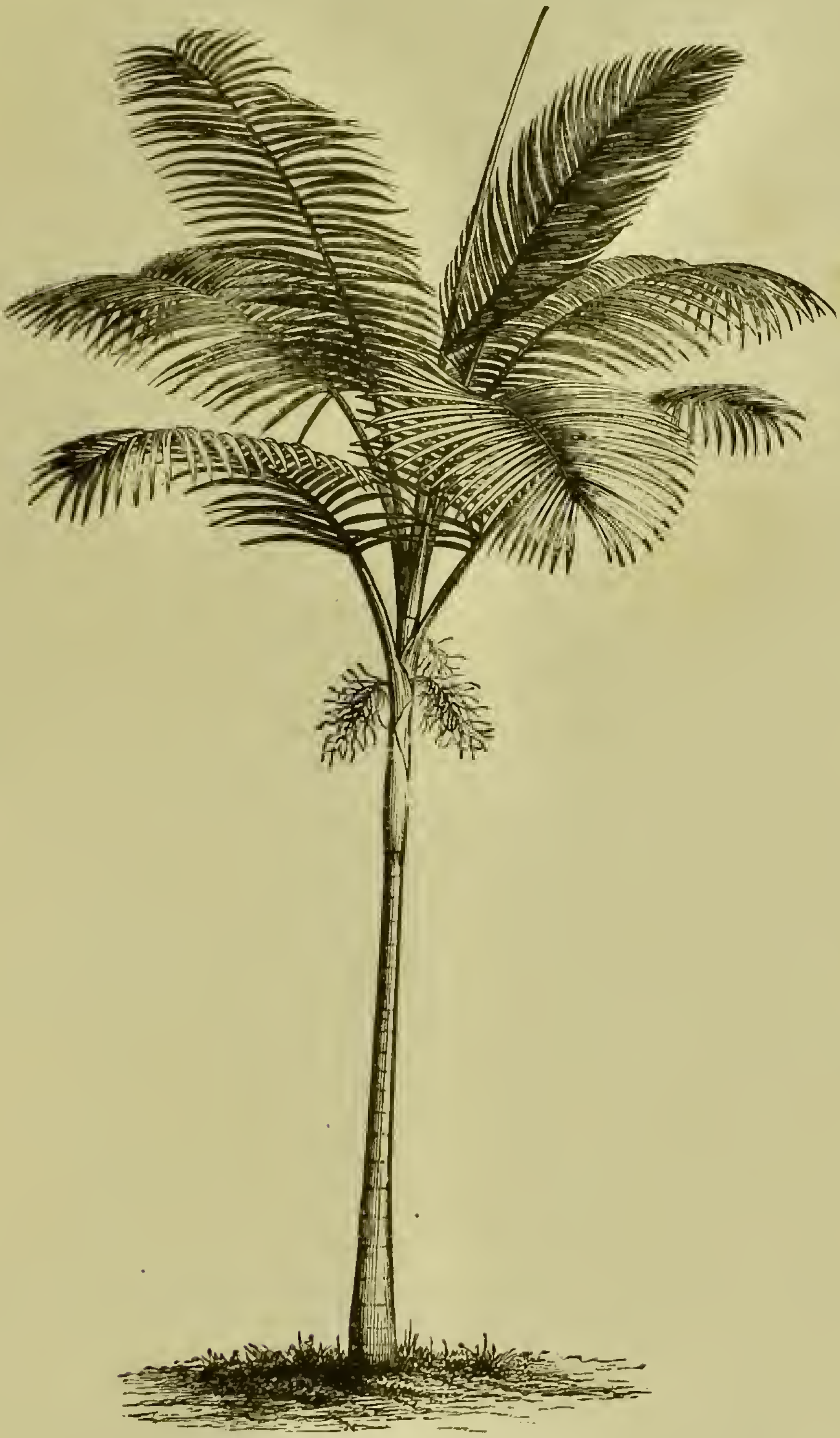


Fig. 471.—*Seaforthia elegans*, a feather-palm (greatly reduced).

seed consisting of a minute embryo buried in a very large oily or horny endosperm, which is at first milky, afterwards solid, and often hollow. The embryo lies in a hollow in the periphery of the endosperm (see Fig. 305, p. 148), and is covered by a thin layer of the latter like a lid. There are about three hundred species of palms, nearly all tropical. The only native European species is the dwarf-palm, *Chamærops humilis* (Fig. 469), which is found as far as 45° north latitude. The uses of palms are innumerable. The inhabitants of entire territories live on the fruits of some kinds, as the date-palm, *Phœnix dactylifera*, in India, Arabia, Persia, and Egypt, and the cocoa-nut palm, *Cocos nucifera*, in all tropical countries. The stems of some species, as *Sagus Rumphii*, *Corypha umbraculifera*, and *Borassus flabelliformis*, contain a starch known in commerce as sago. The leaf-buds of *Areca oleracea*, *Cocos nucifera*, &c., are eaten as vegetables; and the sap which flows from the punctured leaf-buds and stems is fermented, and yields palm-wine. *Arenga saccharifera* from the Moluccas, and *Cocos nucifera*, yield palm-sugar; *Copernica cerifera* palm-wax; and the oily endosperm of many palm-seeds, especially of the West African *Elaeis guineensis*, is used in the production of palm-oil. The endosperm of species of *Phytelephas* is known in commerce under the name 'vegetable ivory.' Palm-bast is obtained from many kinds; that of the leaf-sheath of *Attalea funifera* of Brazil bears the special name 'piassava.' The young pinnate leaves of many palms are manufactured into textile fabrics, hats (*Carludovica palmata* furnishes the Panama-hats), and mats; and the stems are made into canes. [Principal genera:—*Chamædorea*, *Areca*, *Arenga*, *Oreodoxa*, *Ceroxylon*, *Caryota*, *Calamus*, *Sagus*, *Borassus*, *Copernicia*, *Rhapis*, *Chamærops*, *Sabal*, *Phœnix*, *Cocos*, *Elaeis*, *Jubæa*, *Livistonia*.

Cohort VIII. ARALES. Ovary syncarpous; flowers hermaphrodite or unisexual, arranged in a spadix or spike, with or without a spathe, or sunk in pits of a minute scale-like frond; perianth of distinct pieces, white or green, or of minute scales, or absent; fruit a drupe or berry with one, few, or many small albuminous seeds. Herbs, often very large, rarely trees; leaves simple or pinnatifid, very rarely pinnately divided, sometimes netted-veined.

Order 1. AROIDEÆ. Flowers hermaphrodite or unisexual, in cylindric or oblong spadices, enclosed in a green, white, or coloured spathe; perianth absent, or of from four to eight scales; stamens few or many, anthers sessile or on very short filaments, extrorse or opening by pores; ovaries aggregated in from one to four loculi; styles distinct or absent; ovules one or more, basal or parietal; berry one- or more-seeded; seeds minute; endosperm fleshy or floury or absent. Herbs, stemless or with erect or scandent stems; leaves usually large, simple or pinnatifid, usually net-veined (Fig. 194, p. 106). Principal genera:—*Acorus*, *Orontium*, *Anthurium*, *Pothos*, *Calla*, *Richardia*, *Colocasia*, *Caladium*, *Arum.*

To this cohort belong also *Pandanaceæ* (*Pandanus*), and several other less important orders.

Cohort IX. LILIALES. Ovary syncarpous; flowers hermaphrodite, very rarely unisexual, solitary or in spikes, racemes, or panicles, rarely capitate; perianth of six (very rarely four) nearly similar pieces, or gamopetalous and six-lobed, regular (rarely irregular), usually all coloured and petaloid (sometimes coriaceous or subglumaceous); embryo immersed in a copious endosperm (not external to nor in a lateral cavity).

Order 1. LILIACEÆ. Stamens six, hypogynous or perigynous; anthers usually introrse; ovary tri-locular, ovules usually many in each loculus; style entire; fruit a capsule; seed glabrous, with a membranous or crustaceous testa; endosperm fleshy. Stemless herbs or shrubs with a simple or branched trunk; root fascicled or stem bulbous. Principal genera:—*Tulipa*, *Yucca*, *Fritillaria*, *Lilium*, *Gagea*, *Agapanthus*, *Phormium*, *Hemerocallis*, *Aloe*, *Scilla*, *Allium*, *Hyacinthus*, *Ornithogalum*, *Funkia*, *Asphodelus*.] Among useful and medicinal species are the *Aloë socotrina*, the *Scilla* or squill, the various species of *Allium* which yield the onion, leek, garlick, &c., the *Asparagus*, [*Dracæna* or dragon's blood], and *Phormium tenax* or New Zealand flax.

[Mr. Bentham, in a paper read before the Linnean Society, and only recently published, arranges the monocotyledonous orders in four series, *viz.* :—1. EPIGYNÆ. Flowers with a double, usually petaloid, perianth; ovary usually inferior, syncarpous. 2. CORONARIEÆ. Flowers with a double, usually petaloid, perianth; ovary superior, almost always syncarpous. 3. NUDIFLORÆ. Flowers usually achlamydeous, or with a dry scarious perianth; ovary mostly apocarpous. 4. GLUMALES. Perianth replaced by membranous scales (pales or lodicules); ovary always uniovular. The orders are arranged thus in the four series :—

I. EPIGYNÆ.

Hydrocharideæ.
Scitamineæ (including Musaceæ, &c.).
Orchideæ.
Burmanniaceæ.
Irideæ.
Amaryllideæ (including Hæmodoraceæ).
Taccaceæ.
Dioscorideæ.
Bromeliaceæ (?).

II. CORONARIEÆ.

Roxburghiaceæ.
Liliaceæ (including Smilaceæ, Melanthaceæ, &c.).
Pontederiaceæ.
Philydraceæ.
Xyrideæ.
Commelynaceæ.
Junceæ.
Palmæ.

III. NUDIFLORÆ.

Pandaneæ.
Aroideæ.
Typhaceæ.
Lemnaceæ.
Naiades (including Juncagineæ).
Alismaceæ (?).

IV. GLUMALES.

Eriocauleæ.
Centrolepideæ.
Restiaceæ.
Cyperaceæ.
Gramineæ.

ED.]

CLASS XIV. *Dicotyledones.*

Dicotyledons are distinguished from Monocotyledons by the embryo having two cotyledons, by the structure of the stem, by the prevalent number of parts in the floral whorls being 4 or 5, and by the leaves being usually net-veined.

The stem consists, as a rule, of four parts, strongly differentiated from one another,—Epidermis, Cortex, Fibrovascular Bundles, and Pith.

A well-developed epidermis provided with stomata and often with subsidiary organs, entirely covers the younger parts. Earlier or later, often even in the first year, it is thrown off by the formation beneath it of a corky tissue, that part of the plant then losing its green colour.

The cortical tissue is very commonly separated into two portions, an outer and an inner cortex. At an early period in its development bast-fibres, bast-vessels, and laticiferous vessels are generally distributed through it, in addition to the parenchymatous tissue which is always present; the vessels containing, according to circumstances, chlorophyll, starch, crystals, tannin, latex, oil, resin, &c. In the course of its growth the cortex undergoes peculiar changes, with which we are not yet thoroughly acquainted, especially in the case of perennial plants. It is at first greatly stretched from within by the tissue formed beneath it, and finally split. The crevices and wounds thus formed are partly filled up by the new cells of the phloëm-portion of the vascular bundles and those of the intermediate tissue, partly covered up by the cork-tissue. The cortex very commonly exhibits also crevices and furrows on the outside, and is often partially thrown off in the form of *bark*. The portions of the cortex which are fresh formed every year are collectively distinguished as *secondary cortex*, in contradistinction to the layer of *primary cortex* already formed in the growing point. [The inner fibrous portion of the bark is known as the *liber*, and this is often of great tenacity, as in the case of the 'bast' of the lime-tree.

In annual stems, and in perennial stems during the first year, the arrangement of the fibrovascular bundles in Dicotyledons resembles that in Monocotyledons, standing isolated in the fundamental tissue (Fig. 472 A). But in later stages both their structure and arrangement are, with the exception of a few abnormal cases, strikingly different (see Fig. 95, II., p. 68, also Fig. 472 B). They are *open* and *collateral*. The inner portion of each bundle, or that nearest the pith, is always more or less strongly lignified, and forms its *xylem*-portion, the outer part, or that facing the cortex, is composed of thin-walled cells and constitutes the *phloëm* or *bast*-portion, while between the two is always found, while the bundle is still in a growing condition, a portion of intermediate or fundamental tissue, the *intrafascicular cambium*, from which fresh xylem is continually being formed on one side, fresh phloëm on the other side. The phloëm does not form a cylinder surrounding the xylem, as in Vascular Cryptogams, but the xylem and phloëm lie parallel side by side. From the main fibrovascular system of the stem branches of the bundles, the *leaf-traces*, pass into the leaves, and there ramify into the reticulated fibrovascular system of the leaf; but as these do not always bend into the leaf immediately on branching off, but remain as a separate bundle running through a considerable length of the stem, they cause the vascular-bundle-system often to appear very complicated. In addition to the primary bundles, and between them, *secondary fibrovascular bundles* are very often

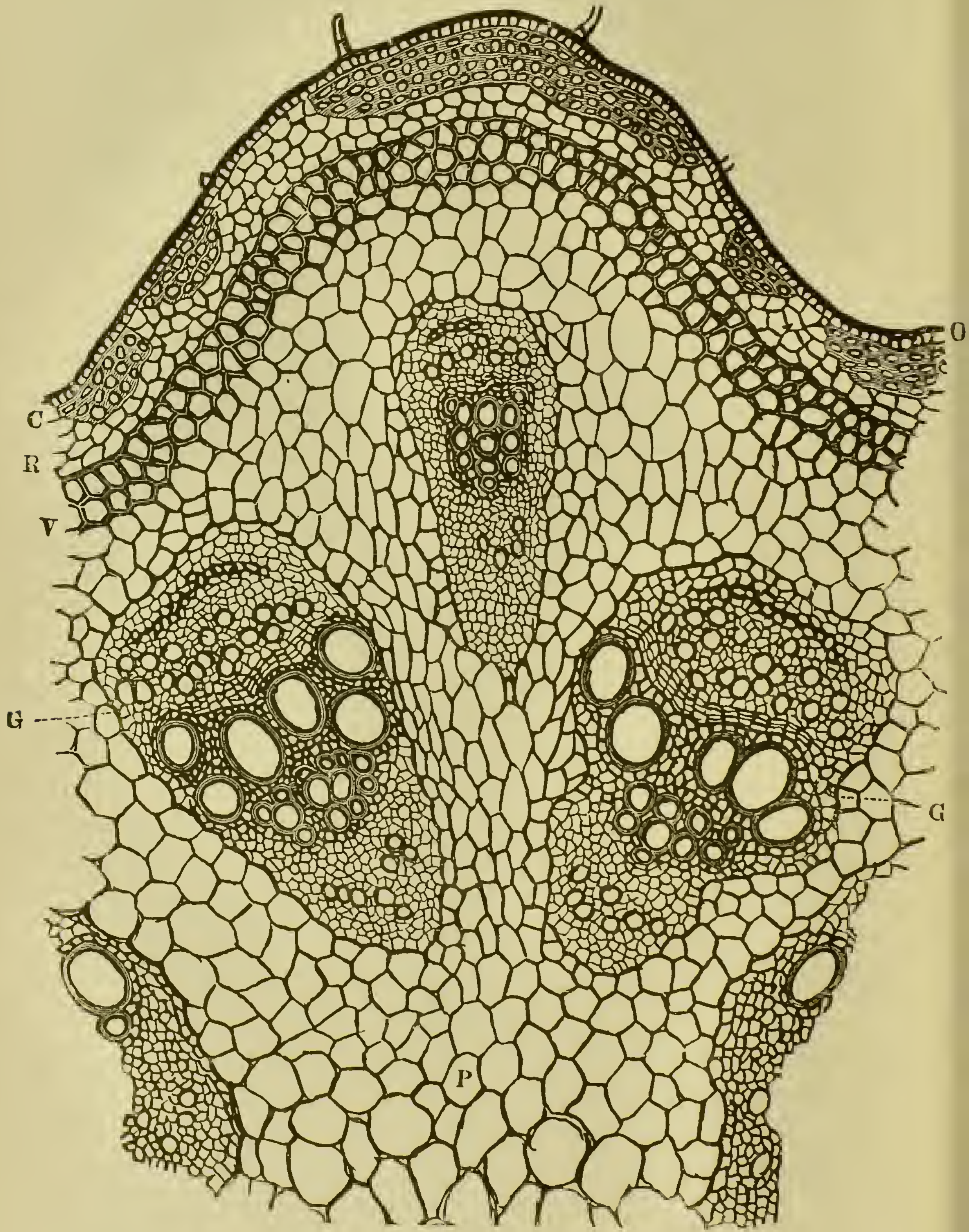


FIG. 472.—A. Part of a transverse section through the stem of *Bryonia alba* ; O epidermis ; C outer cortex (collenchyma) ; R inner cortex ; V ring of lignified cells ; P parenchyma of the stem ; G vascular bundle (× 80).

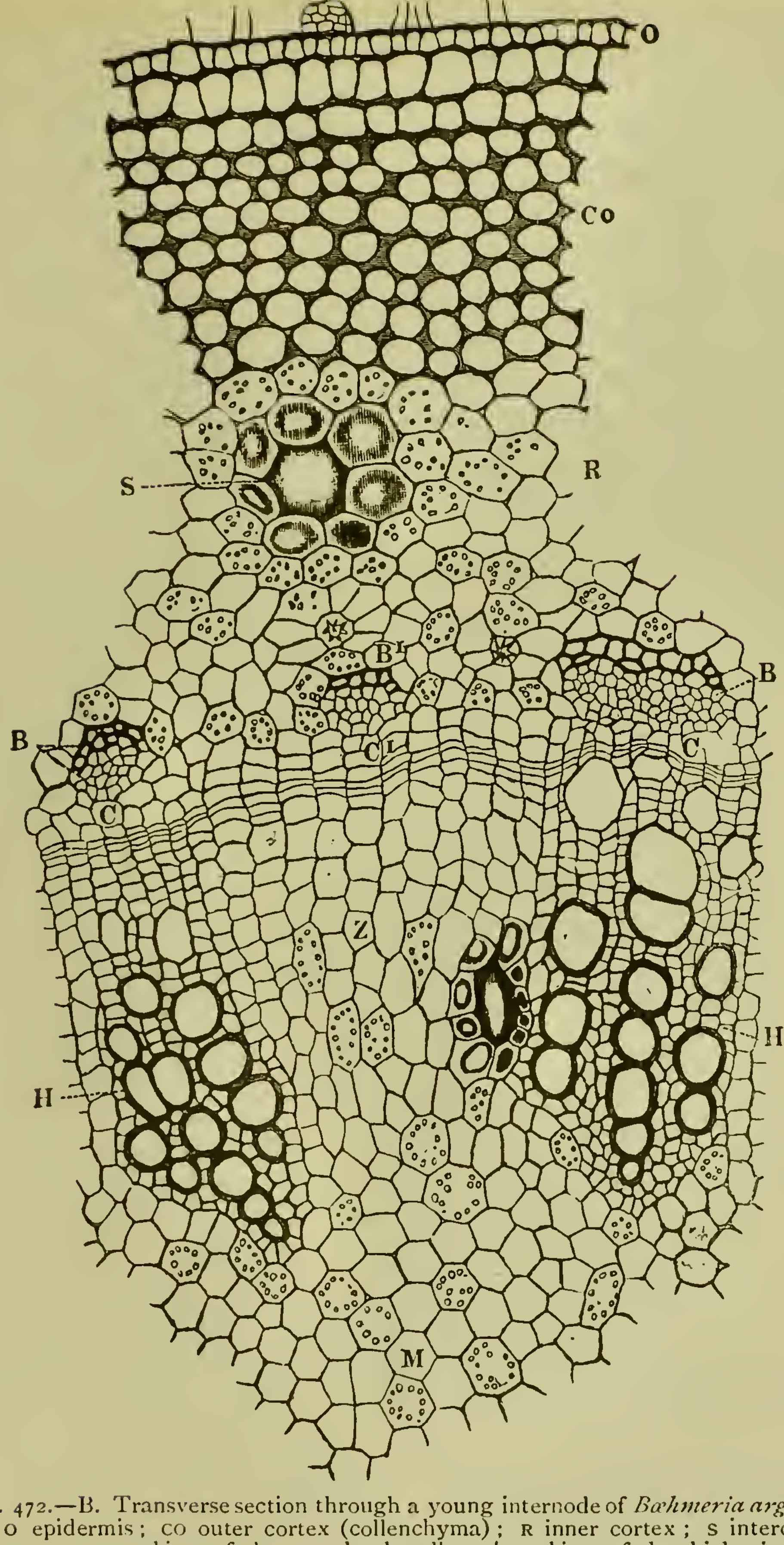


FIG. 472.—B. Transverse section through a young internode of *Bœhmeria argentea*; O epidermis; CO outer cortex (collenchyma); R inner cortex; S intercellular space; C cambium of the vascular bundle; C′ cambium of the thickening-ring; B phloëm-portion; H xylem-portion of the vascular bundle; B′ the phloëm formed from the intermediate cambium; Z medullary ray; M pith (× 120).

formed in the stem of Dicotyledons. Since the whole growth in diameter of the stem and branches is due to the activity of the annual *cambium-ring* formed in the spring of each year outside the latest ring of wood, and its subsequent development during the same year into an additional ring of wood, Dicotyledons are known as *Exogens* in contrast to Endogens. The stem of Exogens is always protected externally by a well-developed bark, among the constituents of which is usually the tissue known as '*vasa propria*,' consisting of elongated cells with thin walls.]

In Fig. 473 we have a diagrammatic representation, after Nägeli, of the course of the vascular bundle through twenty-two internodes of the apex of the stem of *Iberis amara*. Each of the leaves has a vascular bundle, the leaf-traces of which are drawn as far as the points of attachment of the leaves. The internodes are separated by the horizontal lines. Each leaf-trace appears, therefore, when seen in transverse section, to run as a separate bundle through ten or eleven internodes, and invariably unites with the bundle from the fifth leaf below; thus the fifth with the tenth, the tenth with the fifteenth, &c. If transverse sections are made through the internodes, the number of vascular bundles which will be found exposed on each section is indicated by the number given on the left-hand side of the figure. In the leaf-trace of the twenty-second leaf are found fully developed vessels, the probable subsequent course of which is indicated by the dotted line.

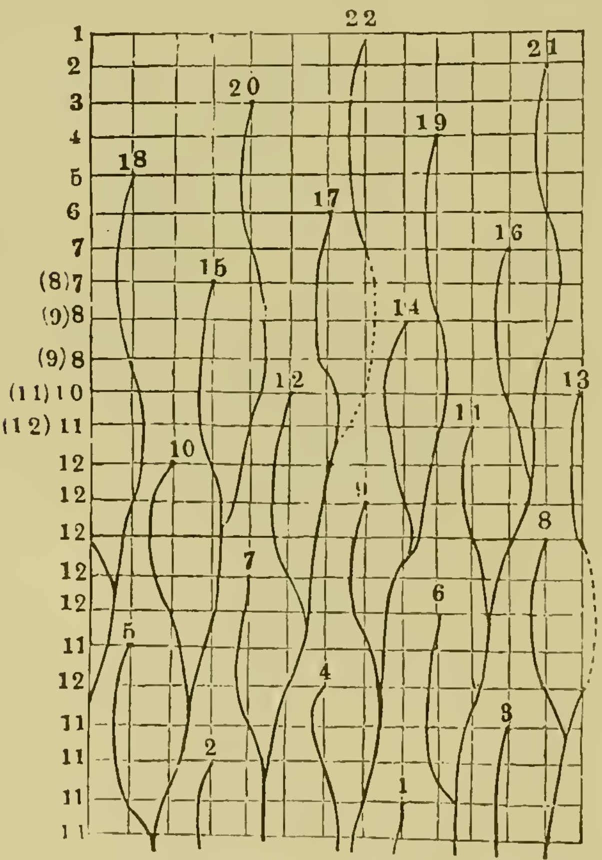


FIG. 473.—Diagrammatic representation of the course of the vascular bundles in *Iberis amara* (after Nägeli).

The course of the vascular bundles is not, however, always so simple as in these cases; for although the bundles of most Dicotyledons run in a vertical direction, they nevertheless occasionally unite, and form combinations which are often rendered yet more complicated by new separations. In the Labiatæ, Umbelliferæ, Balsamineæ, and many other herbaceous plants with jointed stems, the vascular bundles are arranged in a circle, and all run in a parallel direction through the internode. In the node, however, they branch, and are here united with the vascular bundles of the leaves, as we have seen to be the case with Grasses (see p. 341).

The vascular bundles always become closer as they descend in the stem, the separate bundles approaching nearer and nearer to one another through increase in their thickness, often coalescing into a ring which is interrupted only by narrow medullary rays (Fig. 95, II., p. 68).

It will be seen from this description that there is no difference between the mode of growth of annual and perennial Dicotyledons, when young plants of the latter are examined, or shoots still in their first year of growth. After this, growth ceases in annual plants; while in those that are perennial further changes, which will be afterwards referred to, take place in the spring, when vegetation wakes from its winter-rest, and the activity of the cambium recommences.

With reference to the composition of the vascular bundles, a distinction must be drawn between herbaceous and woody plants. In herbaceous plants they are separated by layers of an intermediate tissue of more or less considerable thickness, so that they either lie isolated in the tissue of the stem, or form a ring which is only interrupted by narrower intervals of intermediate tissue (Fig. 472, A). This intermediate tissue, a part of the fundamental tissue, is often composed of cells which are narrower and otherwise of different form from those of the pith and cortex, and it then constitutes the *medullary rays.* The vascular bundles grow for some time by means of the cambium which lies between their xylem- and phloëm-portion. The xylem-portion consists of elongated wood-cells, which sometimes resemble an elongated parenchymatous, sometimes a fusiform prosenchymatous tissue, and in addition of vessels and a thin-walled parenchyma that is but little or not at all lignified; while the phloëm-portion contains on its outer side a bundle of bast-fibres. In contact with it on the inside are thin-walled sieve-tubes and elongated parenchymatous cells. In many plants phloëm-cells are also formed next the pith on the axial side of the vascular bundle; in others laticiferous vessels also occur, usually in the phloëm-portion of the vascular bundle, but also in the cortex. [The portion of the xylem of the innermost bundles of the stem frequently forms a closed ring completely enclosing the pith, and this is then known as the *medullary sheath*; it consists chiefly of spiral vessels.]

The vascular bundles of woody dicotyledonous plants have, at the end of their first year of growth, the structure already described, but are already distinguished by the regularity of their phloëm-bundles, as well as by possessing vessels dispersed through the xylem. The stems of many tropical trees in which the growth is never subject to intermission, as the cocoa- and coffee-bush, remain in this condition, and only gradually increase in diameter by the formation of portions of the vascular bundles exactly resembling those already in existence. But in those tropical trees and shrubs which cast their leaves periodically and have closed buds, like the bread-fruit tree, the activity of the thickening-ring is renewed afresh on the recurrence of the active period of vegetation, as in our deciduous trees; and fresh medullary rays and new xylem- and phloëm-portions of the vascular bundles are formed in exact continuation of the similar parts already in existence. This process is repeated every year, a new layer of cells being annually separated on each side of the thickening-ring, which may even be recognised at a later period as a sharply defined *annual ring* (Fig. 95, II. p. 68).

There may be several reasons for this sharp definition of the separate annual rings. It is possible that the cells formed in the spring, those of the spring-wood, are larger than those of the autumn-wood (see Fig. 479, p. 373); or their walls may be thinner, or the cells otherwise of a different kind; and the abundance and size of the vessels in the spring-wood must also be taken into account. The structure of the root corresponds to that of the stem in the presence or absence of annual rings. The separate annual rings are not always of a uniform thickness, but are often more strongly developed on one side than on the other. From these facts it is possible to form an idea of the life of the tree during each year of its growth. Its age is estimated from the number of these rings; from their breadth it is known what years were favourable, and what unfavourable to its growth; and some knowledge can even be attained respecting the growth of the roots, since the growth of any side of the stem is known to correspond nearly to the development of the roots that branch out on that side.

Sometimes even in the earliest, but always in the later years, the vascular bundles become penetrated in a fanlike manner by new parenchymatous cells formed inside them and arranged in bands, the *secondary medullary rays.* Those cambium-cells which were at one time called cells of the medullary rays, always produce only the same kind of cells; so that the secondary medullary rays, when seen in transverse section, always reach to the thickening-ring; but they never get as far as the pith. The breadth of these rays varies in different plants; in some species they are one cell, in others several cells wide; broad and narrow bands sometimes alternate with one another; but they never penetrate through the whole length of the plant, as can be easily seen on tangential sections (Fig. 474). Both the primary and secondary medullary rays are generally easily recognised by the naked eye, and form the pattern on the wood ordinarily known as the 'silver grain.' They consist of parenchymatous cells usually elongated in the radial direction (see Figs. 474, 475).

Both the xylem- and the phloëm-portion of the vascular bundles of the stem of Dicotyledons consist—with the exception of the fundamental tissue of the medullary rays—of elements which may be arranged into three groups :—prosenchyma, parenchyma, and vessels. The prosenchymatous cells of the xylem—which are also called

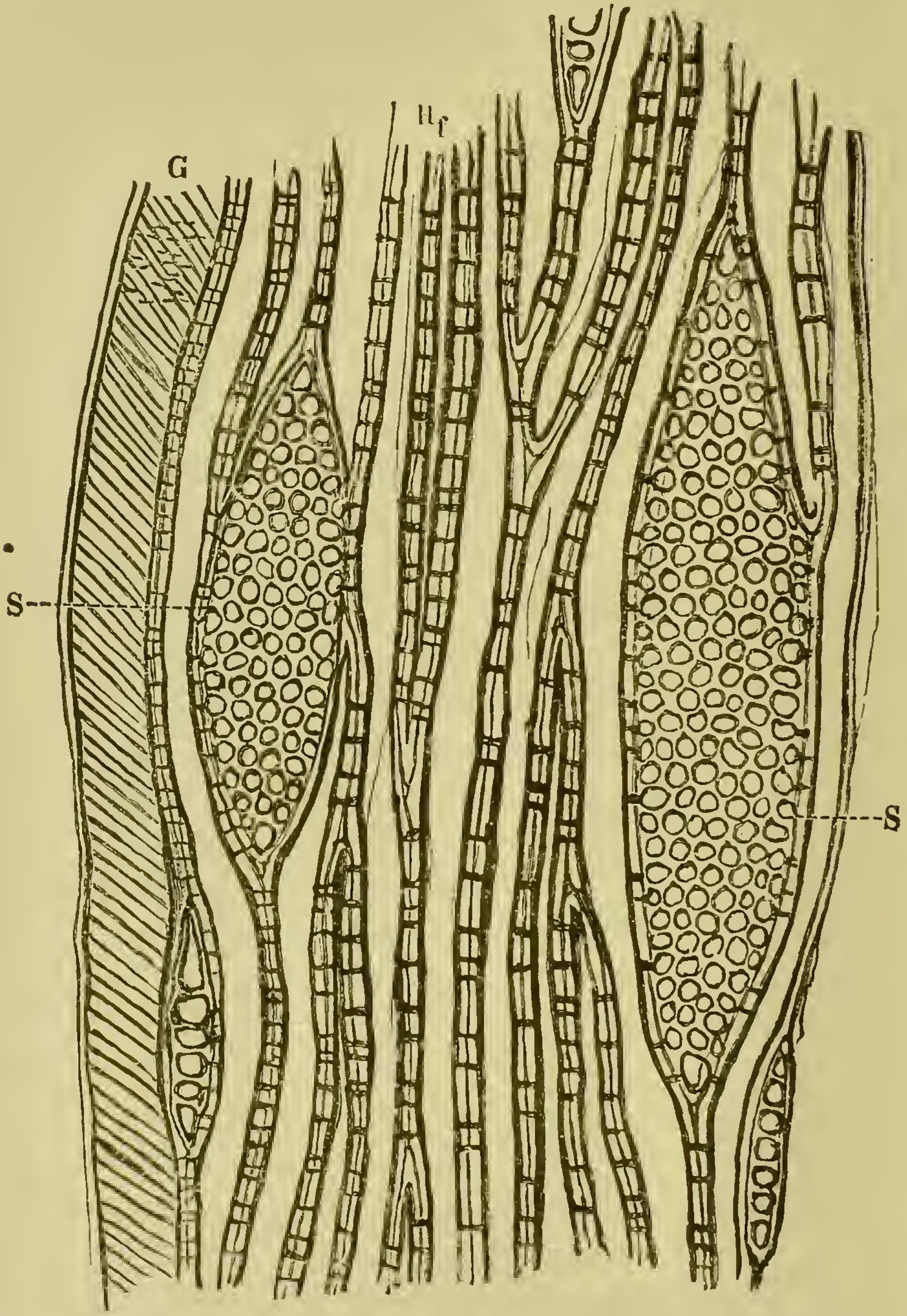


FIG. 474.—Tangential section through the wood of the maple ; G vessels ; H*f* wood-fibres ; S 'silver-grain' (× 200).

wood-cells, wood-fibres, simple bast-like wood-fibres, or libriform fibres—are always fusiform, comparatively strongly thickened and lignified, unbranched, and, as a rule, furnished with extremely small bordered pits (Fig. 14, p. 13). Even when the latter are larger, they differ in size and form from those of the vessels which occur along with them. The

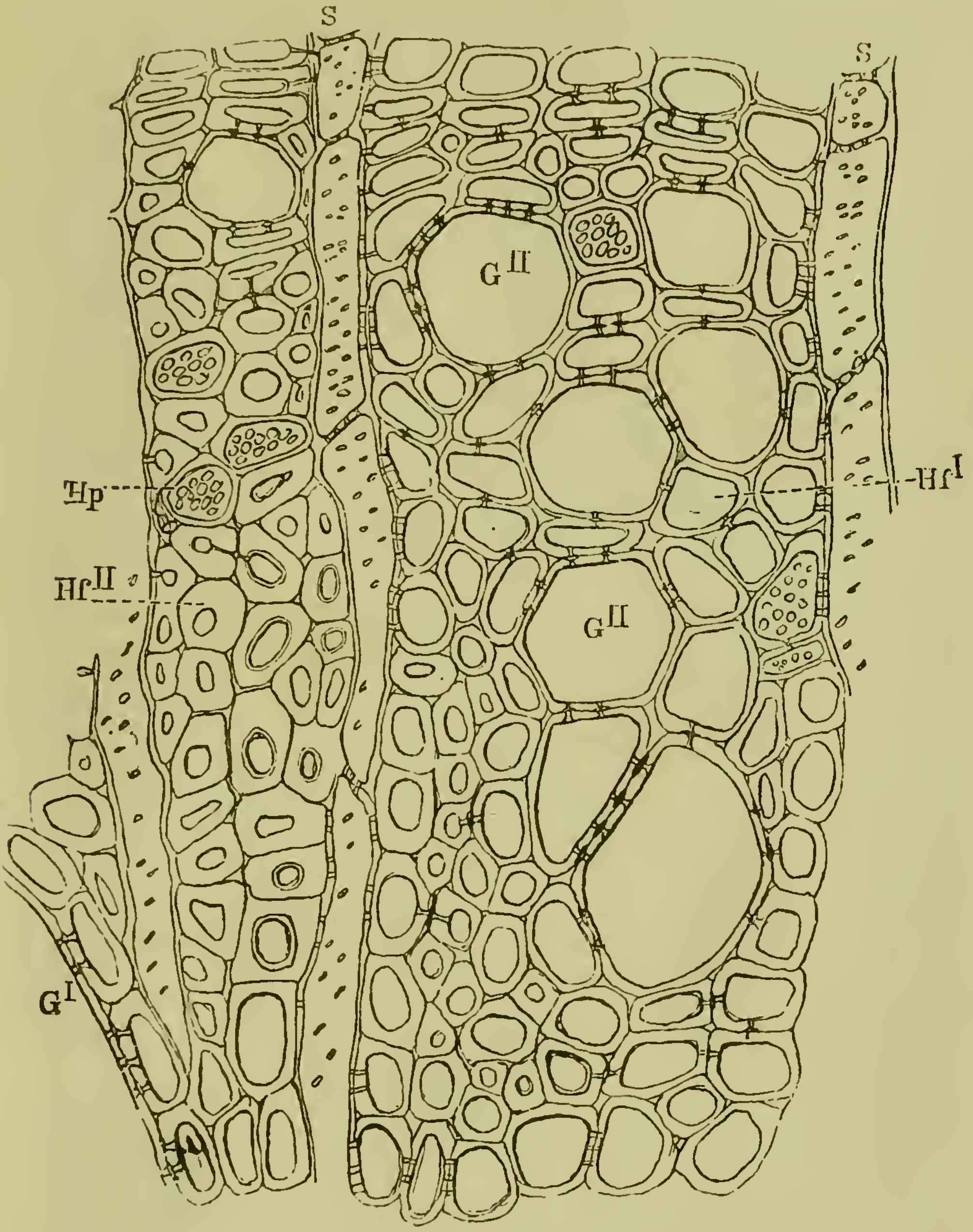


FIG. 475. — Transverse section through the wood of the oak; Hf′ thin-walled, Hf″ strongly thickened wood-fibres; Hp parenchyma of the xylem; S fibres of the 'silver-grain'; G″ small vessels; adjoining G′ is a very large vessel, the size of which is only slightly indicated by the curved border-line.

wood-cells of the inner spring-wood are, as a rule, much less strongly thickened than those of the outer autumn-wood (Fig. 479, p. 373). There is nowhere found in the wood-cells any strongly developed spiral thickening, nor usually even the spiral striation already mentioned (p. 16). In the winter, especially when vegetation is dormant, they usually contain starch. It is comparatively rare for the wood-cells to become septated, when their thickening-layers are nearly completely formed, by one, still more rare by several partition-walls, into daughter-cells, which are then enclosed by the thick-walled wood-cells, and are termed *septated wood-cells.* They rarely possess pits; and, when present, these are cleft-shaped, and placed obliquely in a spiral running to the left. In the winter they usually contain a small quantity of starch.

The parenchymatous cells of the xylem, which are scarcely ever wanting in woody Dicotyledons, are distinguished from the other elements of the vascular bundles by their walls being less strongly thickened, by their having pits which are always closed and never bordered, and by the absence of any spiral thickening. They may be formed in three different ways:—by direct growth from a cambium-cell, or as a daughter-cell either in a cambium- or in a young prosenchymatous cell. In the first case they are isolated; in the two latter cases they are still enclosed within the walls of their parent-cells. These cells also usually contain starch in winter.

The vessels of the xylem have usually bordered pits. In the early condition of the vascular bundles, annular, spiral, and reticulated vessels are found only near the pith, in the *medullary sheath*; the younger parts, on the contrary, contain nothing but pitted vessels. The partition-walls of the separate vascular cells are either horizontal or oblique, and scalariform or penetrated by pits, *i.e.* by a round orifice. A scalariform perforation has at present only been observed in pitted and reticulated, but not in spiral or annular vessels. When the walls of the vessels are not spirally thickened, the pits are most numerous on the side where the vessel borders other vessels or thin-walled wood-cells. At these spots the borders of the pits are also the largest, and the pits themselves always open; in other cases they are always closed. When the walls of the vessels are also thickened spirally, as is the case in the so-called *tracheïds* (Fig. 35, p. 20), this thickening sometimes disappears at those parts of the vessels which adjoin the xylem-parenchyma or medullary rays; but remains, the pits diminishing greatly in number or altogether disappearing, when the tracheids are surrounded by strongly thickened wood-cells. As regards the size or diameter of the vessels, those of the first annual ring are narrower than the succeeding ones; and this is especially the case in the large vessels of the spring-wood. In the oak, for example, the vessels do not attain their full size before the sixth and succeeding rings. The vessels become lignified at an early period, and are then filled with air; it is only when young that they contain sap. When, in a few cases, substances of the nature of gum, resin, or latex occur in them, as in the cherry, these have passed over into them from adjoining elements of the tissue, but have not been formed in them.

The whole of the elements of the xylem need not be present. With regard to their relative position, the separate elements are arranged in rows or groups, or irregularly without any definite arrangement; but even then they are distributed in such a characteristic manner that anyone with experience can determine from a small fragment of wood the genus, or not unfrequently even the species, from which it was taken (Fig. 475). The inner portion of the wood, the cells of which have become firmer and stronger from their walls having undergone lignification for a longer period, is called the *duramen*, in contradistinction to the *alburnum*, or younger layers, the walls of which are less thickened and lignified, and which still contain sap. When a very irregular or twisted course of the separate elements of the wood is caused by branches, or buds, or any similar cause, a very peculiar appearance is imparted to those spots, and they are termed *knots.*

The prosenchymatous cells of the phloëm, which are also called *bast-tubes, bast-fibres*, or *bast-cells*, are as a rule fusiform and unbranched. Septated phloëm-cells, similar to the septated wood-cells (p. 366), are less common than the latter, but occur in the grape-vine and cactus. When young the phloëm-cells contain a protoplasmic sap, at a later period usually air. In the Asclepiadeæ and Apocynaceæ they contain a peculiar greenish sap related to the latex of other plants. The phloëm-parenchyma agrees almost entirely in its development and structure with the xylem. The vessels of the phloëm are sieve-tubes or laticiferous vessels.

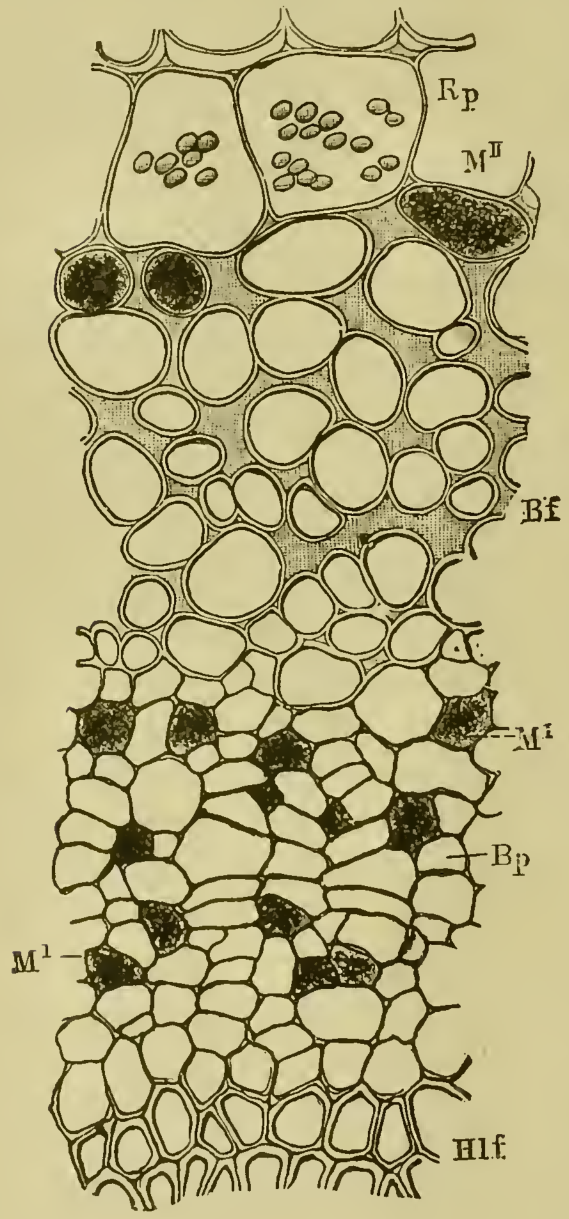


FIG. 476. — Part of a transverse section through the phloëm of the wild lettuce, *Lactuca scariola*: B*f* bast-fibres; B*p* phloëm-parenchyma; M'' outer, M' inner laticiferous vessels; R*p* cortical parenchyma; H*lf* wood-fibres (× 400).

The presence or absence, and the arrangement, of the separate elements in the cortex, are so characteristic of most stems that they can be determined from these characters. A general idea may be obtained by a transverse section through a bast-bundle of the wild lettuce (Fig. 476).

In woody Dicotyledons the pith and the parts of the cortex which do not belong to the vascular bundles are very inconsiderable in comparison with these latter. The pith of the stem only increases for a short time, and then only by the increase in size of the separate cells, and occupies therefore but a small space in comparison with the wood and the fundamental tissue of the medullary rays. It consists of a parenchymatous tissue, in which other elements, as laticiferous vessels, are sometimes, though rarely, enclosed.

Deviations are not unfrequent from the normal structure and course of the vascular bundles here described. In many water-plants, such as *Hippuris*, *Myriophyllum*, *Ceratophyllum*, and *Trapa*, a sheath is formed which limits the increase in diameter of these plants. (Fig. 94, p. 66.)

The roots of Dicotyledons always possess, when young, a thin-walled epidermis, which soon becomes replaced, like that of the stem, by cork-tissue. The cortex of the root is also very similar to that of the stem, consisting of the same elements; and its cells contain the same substances within them. It is very usual for a vascular bundle-sheath to separate the axial bundle from the cortex. While, as has already been mentioned (p. 362), the vascular bundles of the stem have a centrifugal growth, the development of those of the root is in many plants centripetal ; *i.e.*, the first vessels are formed on the outside of the formative tissue, and their further development and lignification advance from the centre towards the axis (Fig. 477, I.). The development of the pith is by this means so much checked that it is always less developed in the root than in the stem ; and in many roots it has entirely disappeared when their vascular bundles have attained their full development. As soon as the vascular bundles have met in the axis of the root, their development progresses outwardly, the new vessels, the bast-bundles, pressing themselves towards the periphery (Fig. 477, II.). A growth of this nature is found especially in herbaceous plants, *e.g.* *Cicuta*, and in those in which the stem has isolated vascular bundles. The root of other Dicotyledons, especially if woody, shows a similar structure to that of the stem. The cell-cavities, both of the xylem- and phloëm-cells, are however considerably larger in the root than in the stem; this being the cause of the smaller specific gravity, and the less value as fuel, of the root as compared with the stem. The annual rings are also often much narrower. The essential peculiarity of the root is the possession of a *root-cap* (see p. 72).

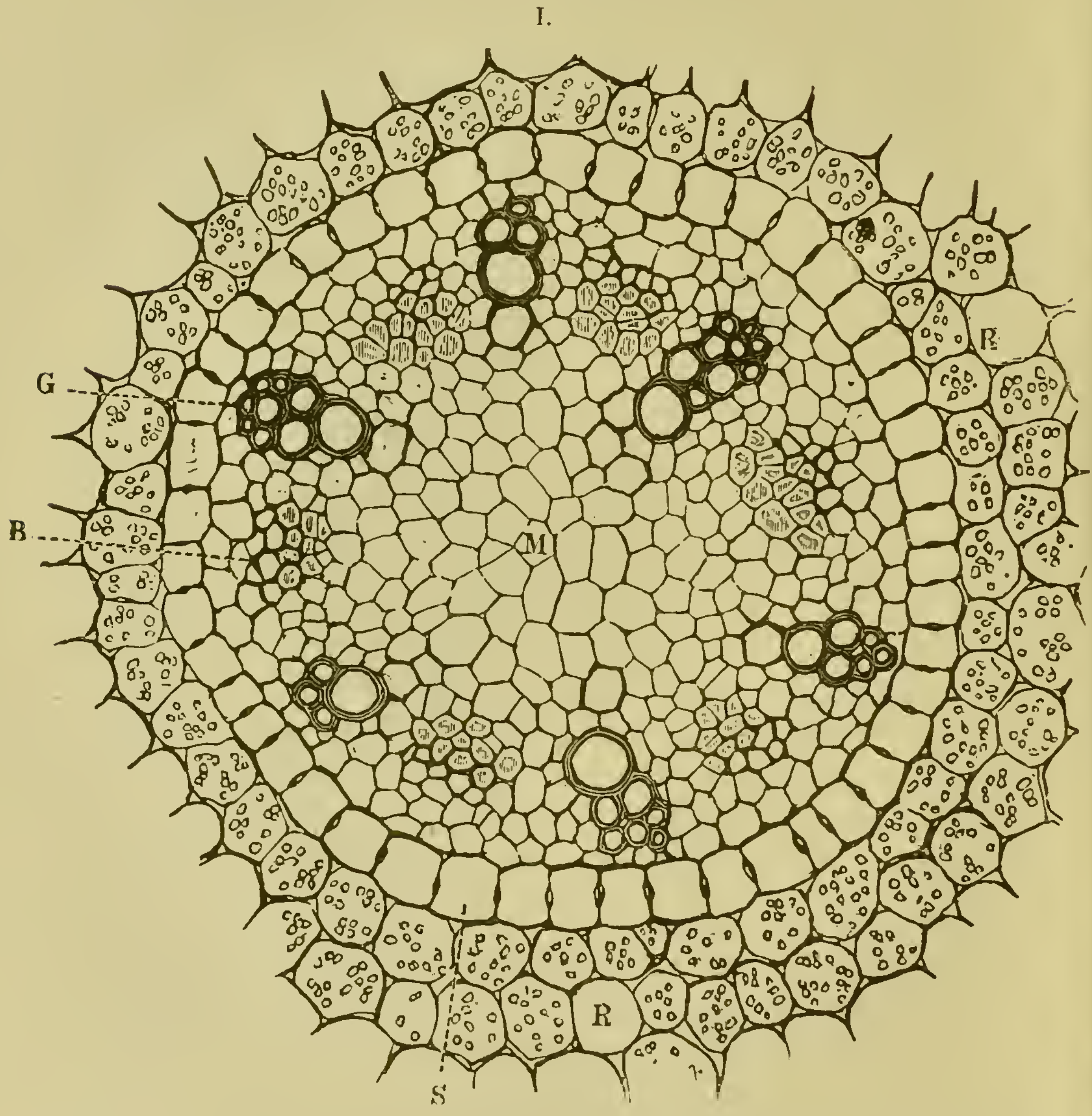


FIG. 477 I.—Transverse section through a young root of *Ranunculus acris*; G group of vessels just formed; B young bast-bundle; S vascular bundle-sheath; R cortical parenchyma; M pith (× 200).

The leaves of Dicotyledons present no essential difference from those of Monocotyledons [except in the arrangement of the vascular bundles or veins].

The structure of the wood of Dicotyledons agrees in its main features with that of Gymnosperms (see p. 333), a class of a generally lower type of organisation. The main distinction lies in the structure of the individual vascular bundles. In Gymnosperms there are in general no true vessels; rows of vascular cells, which occur only in the medullary sheath, taking their place, and even then manifesting only a spiral or reticulate thickening (Fig. 478). The small exotic order of Gnetaceæ furnishes an exception, the whole

II.

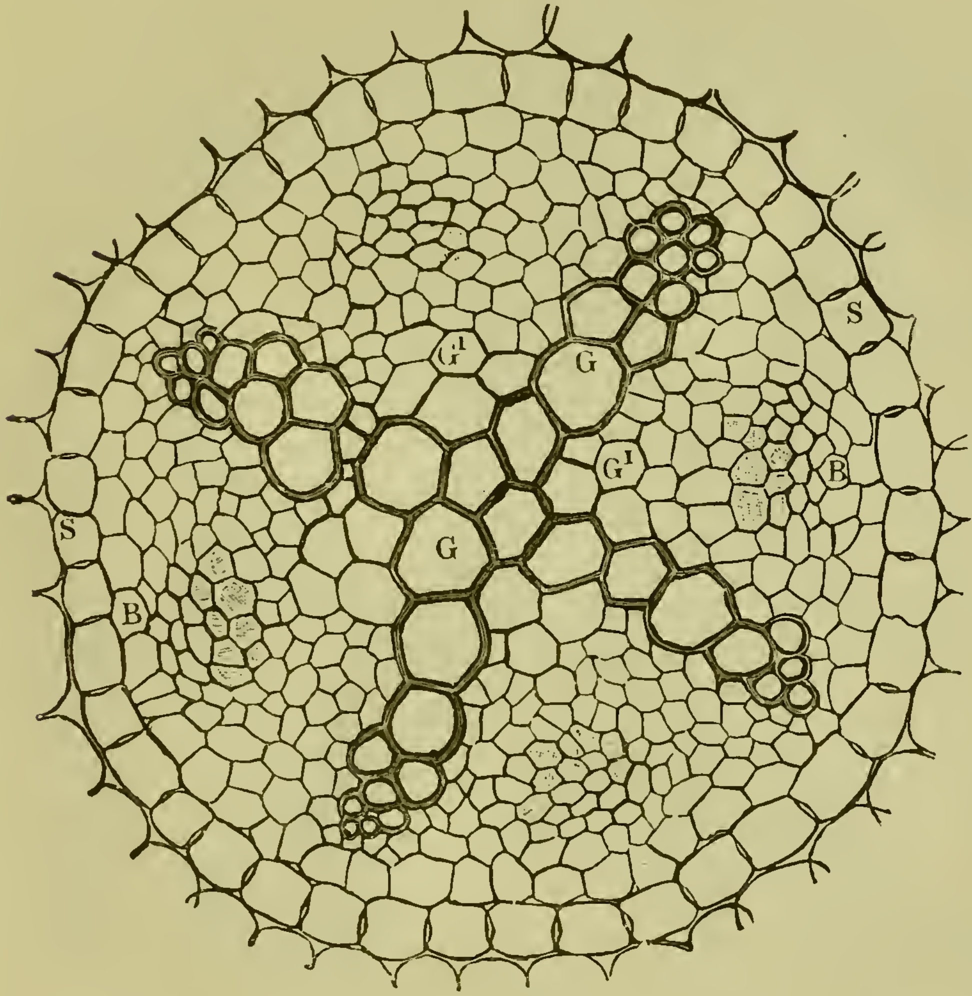


FIG. 477 II.—Transverse section through an older root of *Ranunculus acris*; G vessels formed centripetally; G′ young vessels formed centrifugally; B B bast-bundles; S vascular bundle-sheath (× 200).

of the wood containing true vessels with bordered pits. The wood of Conifers consists mainly of elongated cells possessing as a rule large pits on the side that faces the medullary rays. The characteristic position of the pits, which in the cells of the stem are usually arranged in one, in those of the root often in several rows, as well as that of the resin-passages, which are especially abundant in Coniferæ, form an excellent diagnosis to distinguish the different kinds of wood (Fig. 479). The structure of the swollen stem of

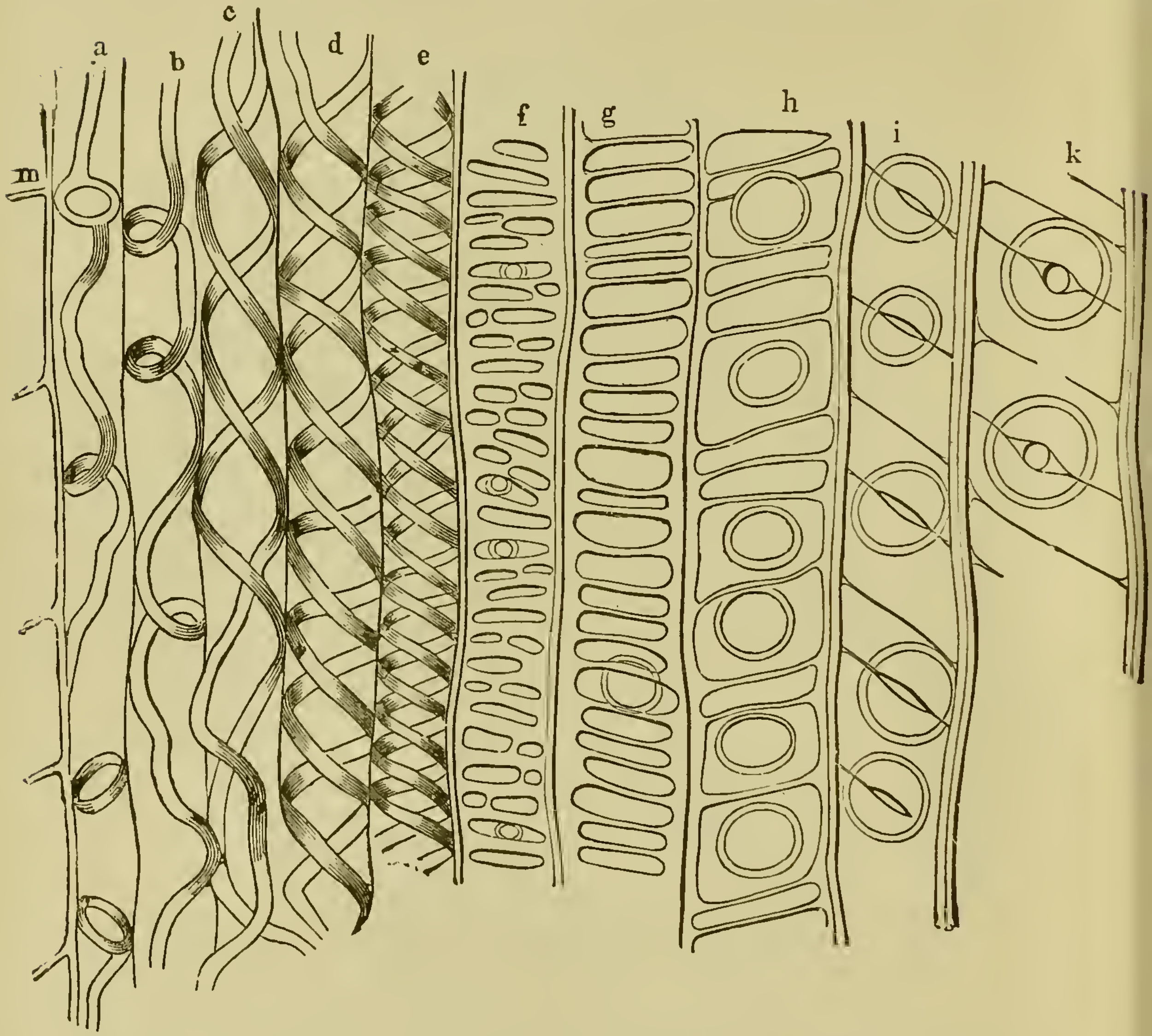


FIG. 478. Longitudinal section through the medullary sheath of the spruce-fir; *a-e* spiral vessels or vascular cells; *f-i* transitional forms into the ordinary wood-fibres; *k* normal wood-fibre; *m* cells of the pith (× 400).

the Cycadeæ is similar, the large pith containing a quantity of starch (known as sago), and surrounded by a com-

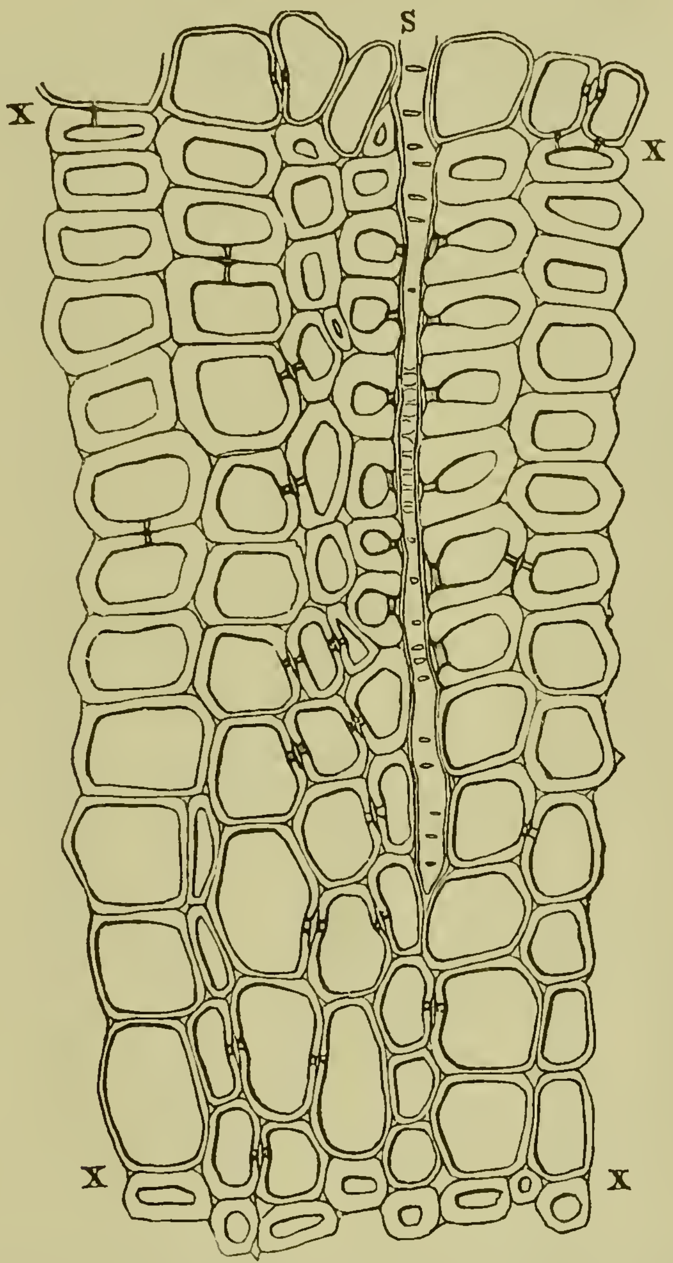


FIG. 479.—Transverse section through the wood of the Scotch fir with moderately large annual ring ; x x boundary of the annual ring ; s silver-grain (× 200).

paratively slightly developed wood. Gum-passages replace in them the resin-passages of the Coniferæ.

[Dicotyledons are subdivided as under, *viz.* :—

DIVISION I. APETALÆ, INCOMPLETÆ, *or* MONOCHLAMYDEÆ.

Perianth consisting of only a single whorl of leaves, or entirely absent, or occasionally of a double whorl of sepaloid leaves.

SUBDIVISION I. *Ovary superior; perianth usually distinct.*

Cohort I. CHENOPODIALES. Flowers usually hermaphrodite; perianth green or coloured, usually regular, sometimes in two whorls, tube short or absent, segments imbricate in bud; ovary of one, rarely several carpels; ovules solitary, rarely two or more, basal; embryo usually coiled or curved. Herbs or shrubs. This cohort includes the orders *Phytolaccaceæ* (*Phytolacca*); *Polygonaceæ* (*Eriogonum*, *Polygonum*, *Fagopyrum*, *Rheum*, *Rumex*); *Amaranthaceæ* (*Amaranthus*, *Celosia*); *Chenopodiaceæ* (*Beta*, *Chenopodium*, *Atriplex*, *Spinacia*, *Salicornia*, *Salsola*); and *Nyctagineæ* (*Mirabilis*, *Buginvillea*).

Cohort II. LAURALES. Flowers usually unisexual; perianth green or coloured, usually regular; ovary unilocular; stigma one; ovule solitary; embryo straight, with or without endosperm. Mostly aromatic trees or shrubs; almost entirely tropical. Orders:—*Monimiaceæ* (*Monimia*, *Laurelia*); *Myristicaceæ* (*Myristica*); *Lauraceæ* (*Cinnamonum*, *Persea*, *Sassafras*, *Laurus*, *Cassytha*, *Camphora*, *Nectandra*, *Oreodaphne*).

Cohort III. DAPHNALES. Flowers usually hermaphrodite; perianth green or coloured, regular or irregular, often tubular; ovary unilocular, rarely bilocular; stigma one; ovule usually solitary, pendulous or suberect; embryo straight, with no or very little endosperm. Trees or shrubs, mostly tropical or southern. Principal orders:—*Thymelæaceæ* (*Daphne*, *Pimelea*); *Elæagnaceæ* (*Hippophaë*, *Elæagnus*); *Proteaceæ* (*Leucodendron*, *Grevillea*, *Banksia*, *Protea*, *Vakea*).

Cohort IV. URTICALES. Flowers diclinous, or less often polygamous or hermaphrodite; perianth green, usually regular, rarely absent; stamens opposite the perianth-lobes or sepals; ovary unilocular, rarely bilocular; stigmas one or two; ovule solitary, micropyle always superior; fruit usually an achene or samara; embryo straight, with or without endosperm. Principal orders:—*Urticaceæ* (*Urtica*, *Bœhmeria*, *Parietaria*); *Moraceæ* (*Artocarpus*, *Ficus*, *Dorstenia*, *Morus*, *Maclura*); *Cannabineæ* (*Cannabis*, *Humulus*); *Ulmaceæ* (*Ulmus*).

Cohort V. AMENTALES. Flowers diclinous, in catkins, cones, or heads; perianth absent or sepaloid, or of one or more bristles, bracts, bracteoles, or scales; ovary uni- or bi-locular; seed without endosperm. Trees or shrubs, with alternate, simple, usually stipulate leaves.]

Order 1. BETULACEÆ.[1] (Fig. 480.) Trees or shrubs, with alternate simple leaves, and free deciduous stipules. Flowers monœcious, both male and female arranged in catkins, and subtended by scale-like bracts. Male flowers in threes in the axil of a bract, and formed of a two- or four-cleft perianth, in front of the teeth of which the stamens are placed; female flowers also in twos or threes in the axil of a bract, but consisting simply of a free ovary with two loculi, in each of which is a pendulous ovule; fruit usually a samara, and seeds exalbuminous. The two genera of this order, *Betula* the birch, and *Alnus* the alder, furnish useful woods. From the bark of the birch is obtained the birch-oil used in the manufacture of Russia-leather, and imparting to it its peculiar odour.

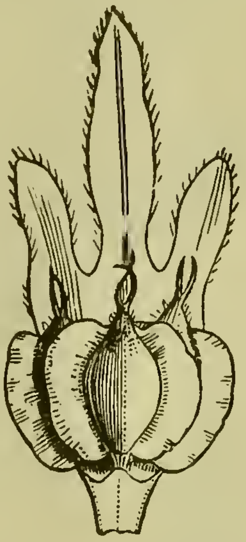


FIG. 480.—Bract of the birch, *Betula*, with three samaræ in its axis.

Order 2. SALICACEÆ. (Fig. 481.) Trees or shrubs, with simple alternate leaves and deciduous stipules. Flowers diœcious, and both male and female always in catkins; instead of perianth, each kind has a few small scales or a glandular or cup-shaped fleshy disc. The male flowers consist, in addition, of from two to twenty-four free or monadelphous stamens; and the female of a free bicarpellary pistil, standing in the axil of a scale, and having generally two stigmas. The unilocular ovary contains a number of pendulous ovules attached to two parietal placentæ; and the fruit is a two-valved capsule; the seeds without endosperm, but furnished with a tuft of hairs. The two genera of which this order is composed, *Salix* the willow, and *Populus* the poplar, are divided into a large number of species, varieties, and hybrids, distributed over the whole globe. The nearer they approach the poles, the smaller are they in stature; and the arctic willow, *Salix polaris*, is only an inch in height. Some species, as *S. purpurea* and *rubra*, unfold their catkins before their leaves; among the best-known species are *S. babylonica* the weeping willow, *S. vitellina* the osier, *S. alba* the white willow, *Populus tremula* the aspen, *P. nigra* the black poplar, *P. pyramidalis* the Lombardy poplar, *P. alba* the white poplar, and *P. balsamifera* the American balsam poplar. The wood of some species is valuable on account of its toughness and elasticity, and is used for basket-work and other purposes. The bark of others, as *S. pentandra* and *fragilis*, is officinal, affording the substance known as salicine.

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[1] [The orders Betulaceæ and Salicaceæ, together with Cupuliferæ and Corylaceæ from the cohort Quernales, constitute the Amentaceæ of the syllabus of the University of London.—ED.]

To this cohort belong also the small orders *Platanaceæ* (*Platanus*); *Myricaceæ* (*Myrica*); and *Casuarinaceæ* (*Casuarina*).

[Cohort VI. EUPHORBIALES. Flowers hermaphrodite or diclinous; perianth green, coloured or absent, ovary bi- or multi locular; ovules one or many in each loculus, pendulous, anatropous; fruit usually a uni- or multi-locular capsule; seeds solitary or numerous.]

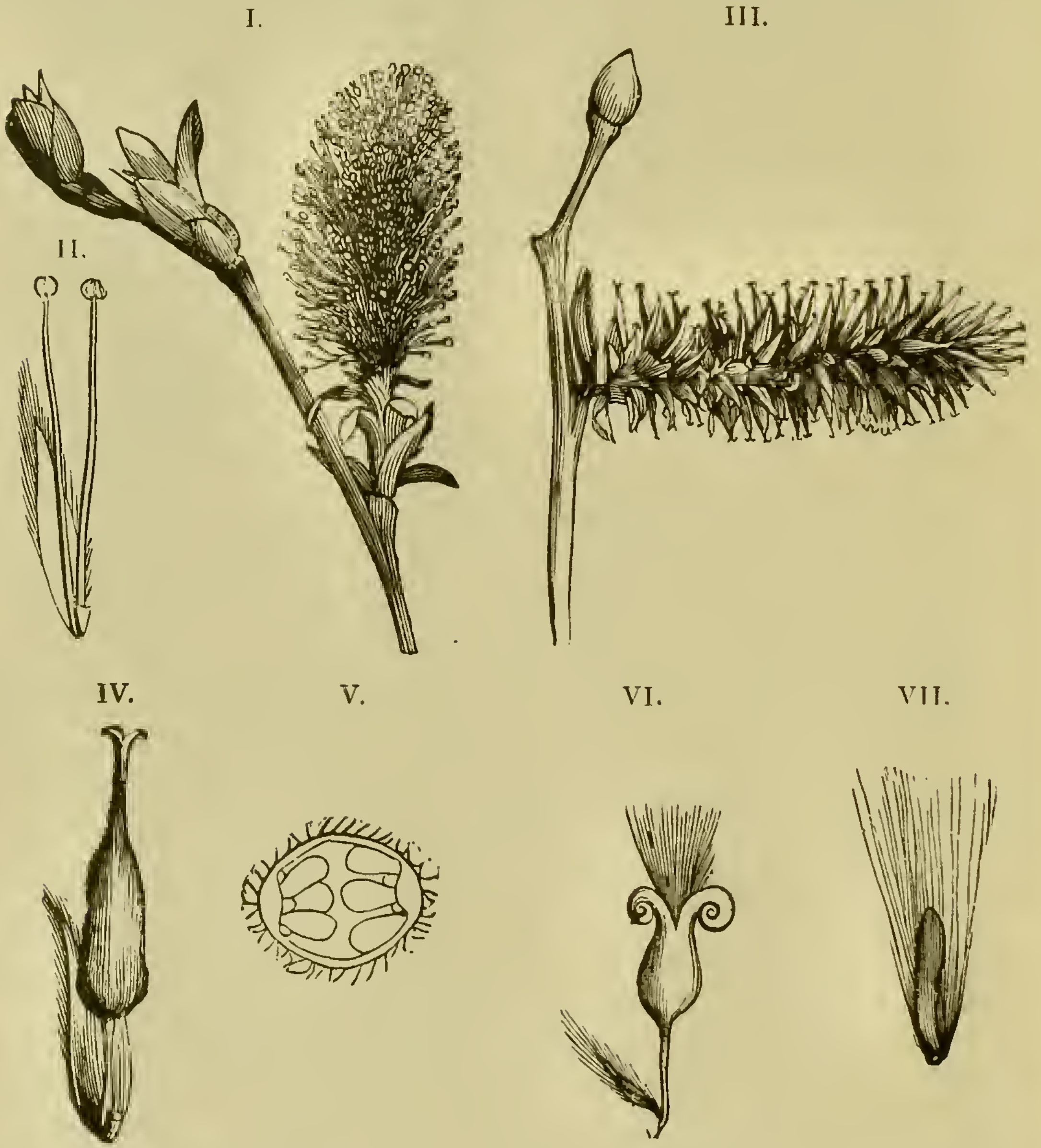


FIG. 481.—Sallow, *Salix Caprea*; I. male catkin (natural size); II. male flower (magnified); III. female catkin (natural size); IV. female flower (magnified); V. transverse section of ovary; VI. fruit; VII. ripe seed (magnified).

Order I. EUPHORBIACEÆ. (Figs. 482, 483.) Trees, shrubs, or herbs, containing a watery, often acrid, more rarely tasteless latex. The stem of some species is fleshy, resembling that of the cactus, and is then leafless, or the leaves are replaced by small scales, spines, or hairs. Flowers solitary or collected into an inflorescence, and hermaphrodite, monœcious, or diœcious. The tropical species especially are so polymorphic, and yet so nearly related, that their classification is attended with extreme difficulty. The genera of northern Europe agree in never having a double perianth separable into calyx and corolla ; in the styles and stigmas being distinct ; in the fruit being a three-valved

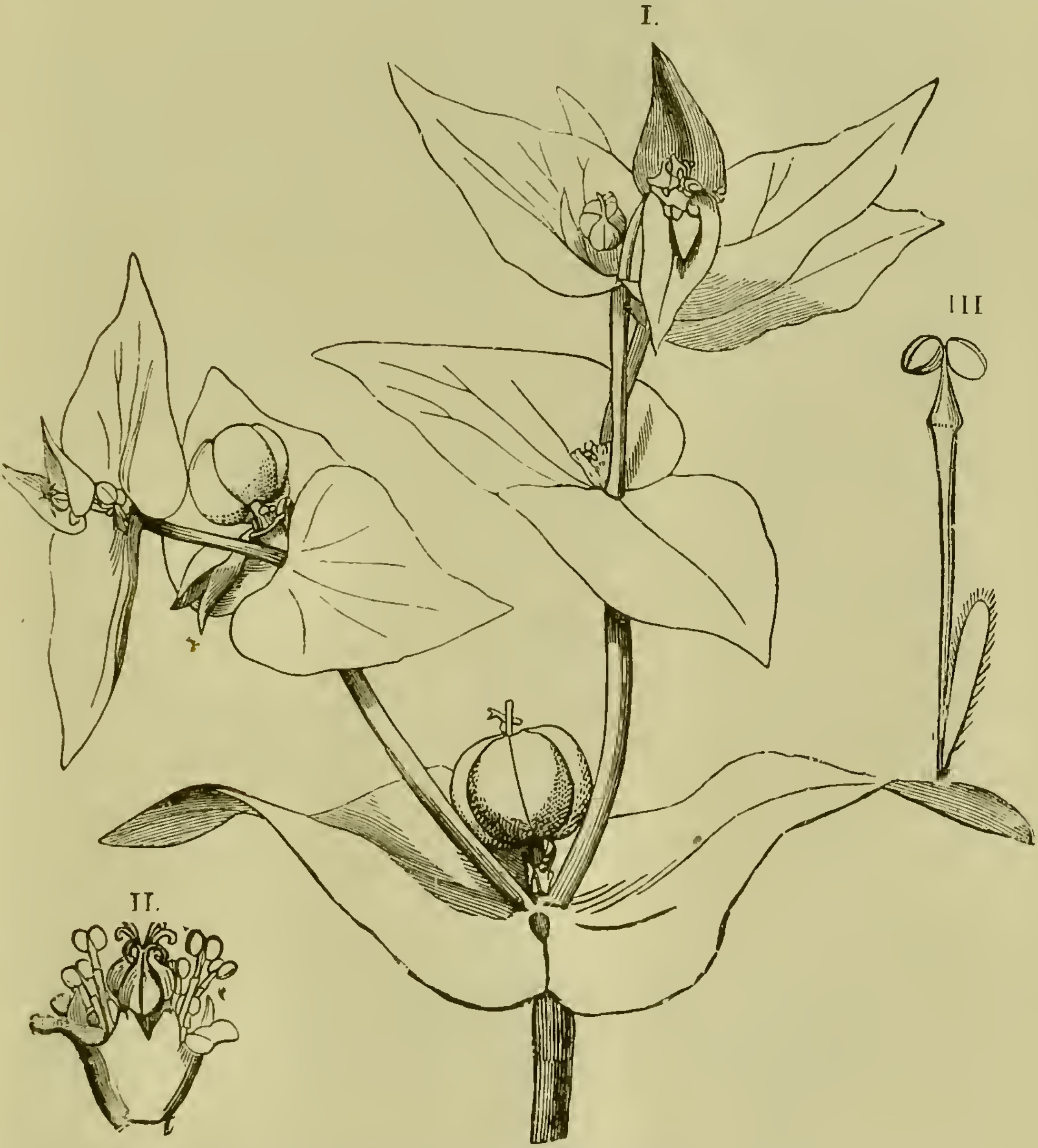


FIG. 482.—*Euphorbia Lathyris* : I. part of a plant (natural size) ; II. inflorescence; III. male flower (magnified).

capsule, the valves separating elastically from a central axis ; and in the seed being straight, the embryo lying in the centre of a fleshy and oily endosperm. [Among the more important genera of this very large order, which is divided into a number of suborders, are *Phyllanthus*, *Anti-*

desma, *Croton*, *Hippomane*, *Crozophora*, *Mercurialis*, *Acalypha*, *Cælebogyne*, *Ricinus*, *Manihot*, *Jatropha*, *Euphorbia*, *Siphonia*.] A large number of species possess a poisonous latex, which is especially dangerous in some tropical kinds, as *Hippomane Mancinella* of tropical America. On the other hand the dried latex of *Euphorbia officinarum* and of some other African species, is used in medicine under the name euphorbium ; and of late years also the oil-glands and hairs of the East Indian *Rottlera tinctoria*, known as camala, and previously used only as a dye. Other officinal preparations are cascarilla, the bark of *Croton Eluteria*; castor-oil, derived from the seeds of *Ricinus communis*, and croton-oil from those of *Croton Tiglium*. Shell-lac is obtained from the East-Indian *Croton lacciferum* ; caoutchouc or india-rubber from the dried latex of *Siphonia elastica* and *brasiliensis* from Brazil and Guiana. The starchy rhizome of *Manihot utilissima*, cultivated in many tropical countries and especially in America, affords, after the removal of the acrid latex, tapioca, from which cassava-bread is made. The castor-oil plant is cultivated for the beauty of its foliage.

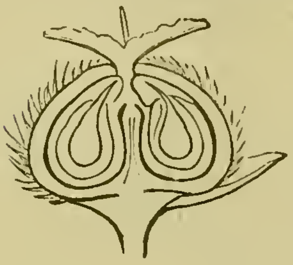


FIG. 483.—Longitudinal section through the fruit of *Mercurialis perennis* (magnified).

[To this cohort belong also *Buxaceæ* (*Buxus*), and several other unimportant orders.

Cohort VII. PIPERALES. Flowers hermaphrodite or diclinous, usually in spikes or catkins ; perianth rudimentary or absent ; ovary unilocular with a single ovule, or of several free carpels with two or more ovules. Orders :—*Piperaceæ* (*Piper*, *Cubeba*, *Peperomia*) ; *Chloranthaceæ* (*Chloranthus*).

SUBDIVISION II. *Ovary inferior ; perianth more or less distinct in either male or female flowers, or both.*

Cohort VIII. ASARALES. Flowers hermaphrodite or diclinous; perianth usually coloured ; stamens epigynous in the hermaphrodite flowers ; ovary uni- or multi-locular ; fruit a capsule or berry. Orders :—*Aristolochiaceæ* (*Asarum*, *Aristolochia*) ; *Rafflesiaceæ* (*Rafflesia*, *Hydnora*, *Cytinus*).

Cohort IX. QUERNALES. Flowers diclinous ; the male flowers in catkins, the female solitary or in spikes ; perianth green, that of the male flower lobed or reduced to a scale, of the female flower minute, 2–6-lobed or toothed ; ovary 1–6-locular ; ovule solitary basal, or one or more pendulous ; fruit one-seeded ; seed without endosperm. Trees with simple or compound leaves].

Order I. CUPULIFERÆ. Trees or shrubs with simple alternate leaves, deciduous stipules, and monœcious flowers. Male flowers arranged in catkins, with a 4- or 5-cleft perianth or none at all, and five to ten stamens attached to the perianth or bracts; female flowers solitary, or in clusters or spikes, their perianth superior, with a toothed often almost obsolete margin ; ovary with from two to six stigmas, and the same number of loculi; in each loculus one or two pendulous ovules with two integuments. Fruit indehiscent, and, by abortion, usually unilocular and one-seeded, and surrounded at its base by a cup-shaped envelope, the *cupule*, as in the oak, or entirely enclosed within it, as in the beech. This cupule proceeds from an inferior disc (Fig. 303, p. 147), and not from a leaf of the perianth, as in the Corylaceæ. The seed is without endosperm, and has a large embryo with thick fleshy cotyledons. The fruit of the Spanish or sweet chestnut, *Castanea vesca*, is edible. The two British oaks *Quercus sessiliflora* (*Robur*) and *pedunculata*, and *Q. Cerris* and *infectoria* from Asia Minor and Turkey, are valuable for their wood, and the latter especially for its galls, from which tannin is obtained. Almost the whole of the cork of commerce is the produce of *Q. suber* from Spain, South Italy, and northern Africa. The wood of *Q. tinctoria* of North America is used as a yellow dye. The beech, *Fagus sylvatica*, is valuable for its wood and the oil of its seeds.

Order 2. CORYLACEÆ. (Figs. 484, 485.) This order is so closely allied on the one hand to the Cupuliferæ, on the other hand to the Betulaceæ, that we may trace a gradual transition between the three. From the Cupuliferæ it is distinguished by the presence of a spurious foliar cupule, and by the ovules having only a single integument ; from the Betulaceæ by the cupule, the superior though usually rudimentary perianth of the female flowers, the absence of a perianth to the male flowers, and by each anther-lobe bearing a tuft of hairs (see Fig. 268, p. 137). The best-known representatives of the order are the hornbeam, *Carpinus Betulus*, valuable for its timber, and the hazel or filbert, *Corylus Avellana*, for its fruit and wood.

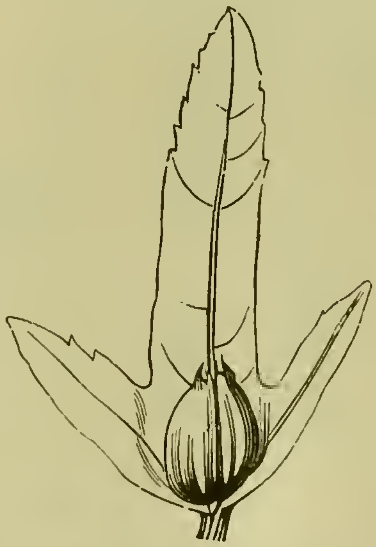


FIG. 484.—Fruit of the hornbeam, *Carpinus Betulus*, with its three-lobed perianth (natural size).

[To this cohort belongs also the order *Juglandeæ* (*Juglans*, *Carya*).

Cohort X. SANTALALES. Flowers hermaphrodite or diclinous ; perianth usually conspicuous, coloured, polymorphic, and valvate ; ovary uni- or multi-locular, loculi with one or many ovules, ovules usually reduced to a naked nucleus ; fruit a one-seeded berry or drupe. Parasitic herbs or shrubs. Orders :—*Loranthaceæ* (*Loranthus, Viscum, Mysodendron*); *Santalaceæ* (*Thesium, Santalum*); *Balanophoraceæ* (*Cynomorium, Balanophora, Langsdorffia*).

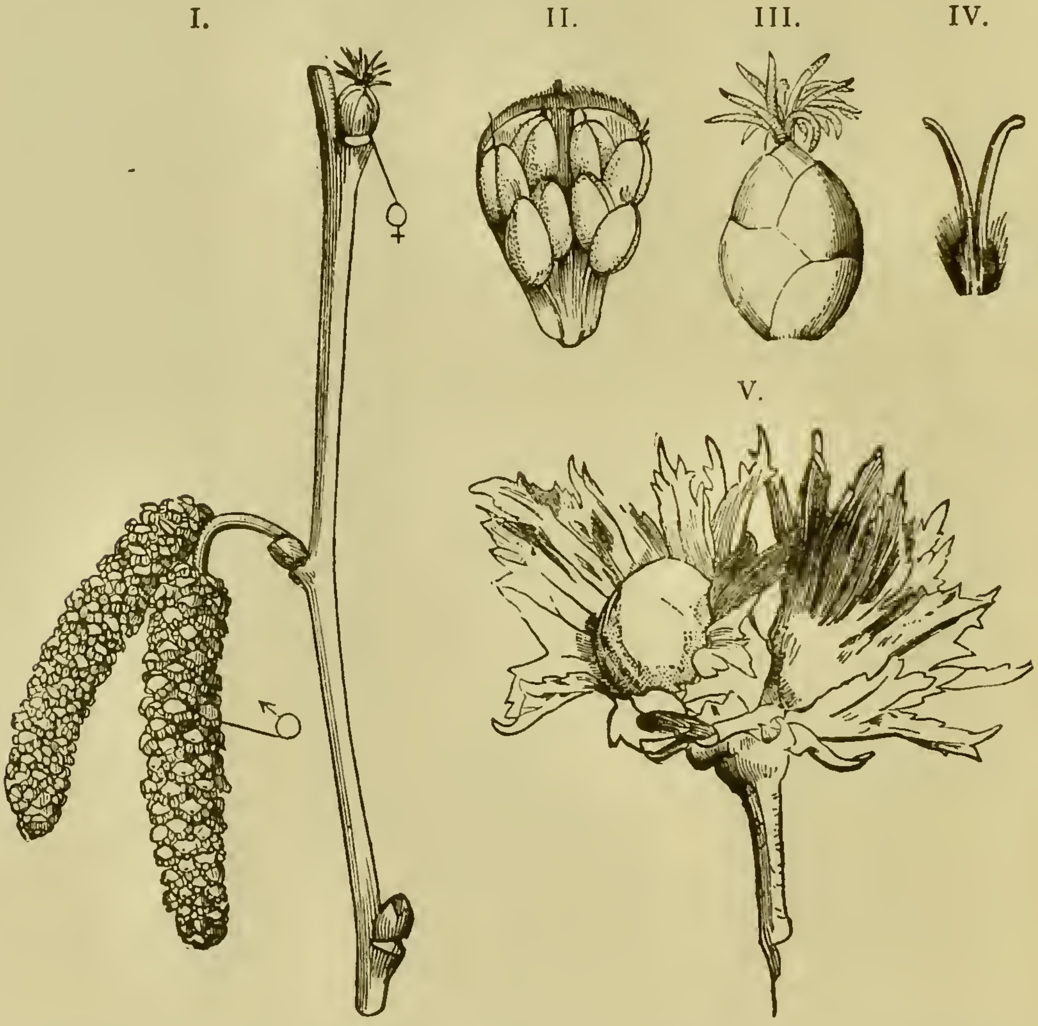


FIG. 485.—The hazel, *Corylus Avellana* : I. branch with male and female flowers (natural size); II. male flower ; III. female inflorescence ; IV. female flower (magnified); V. fruit (nut) with laciniated spurious cupule (natural size).

DIVISION II. GAMOPETALÆ.—*Flowers furnished with both calyx and corolla, the latter gamopetalous.*

SUBDIVISION I. *Ovary superior* (*rarely inferior*).

SECTION I. *Flowers very irregular* (*rarely regular*).

Cohort I. PERSONALES. Corolla gamopetalous, hypogynous, often bilabiate ; stamens fewer than the corolla-lobes, rarely as many, unequal, usually four and didynamous, rarely two ; ovary 1–2- rarely

4-locular; style simple; stigmas one or two; ovules usually very numerous; fruit usually a capsule. Herbs, rarely shrubs or trees, with exstipulate leaves.]

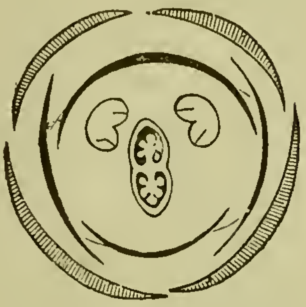


Fig. 487.—Floral diagram of *Veronica* (Scrophulariaceæ).

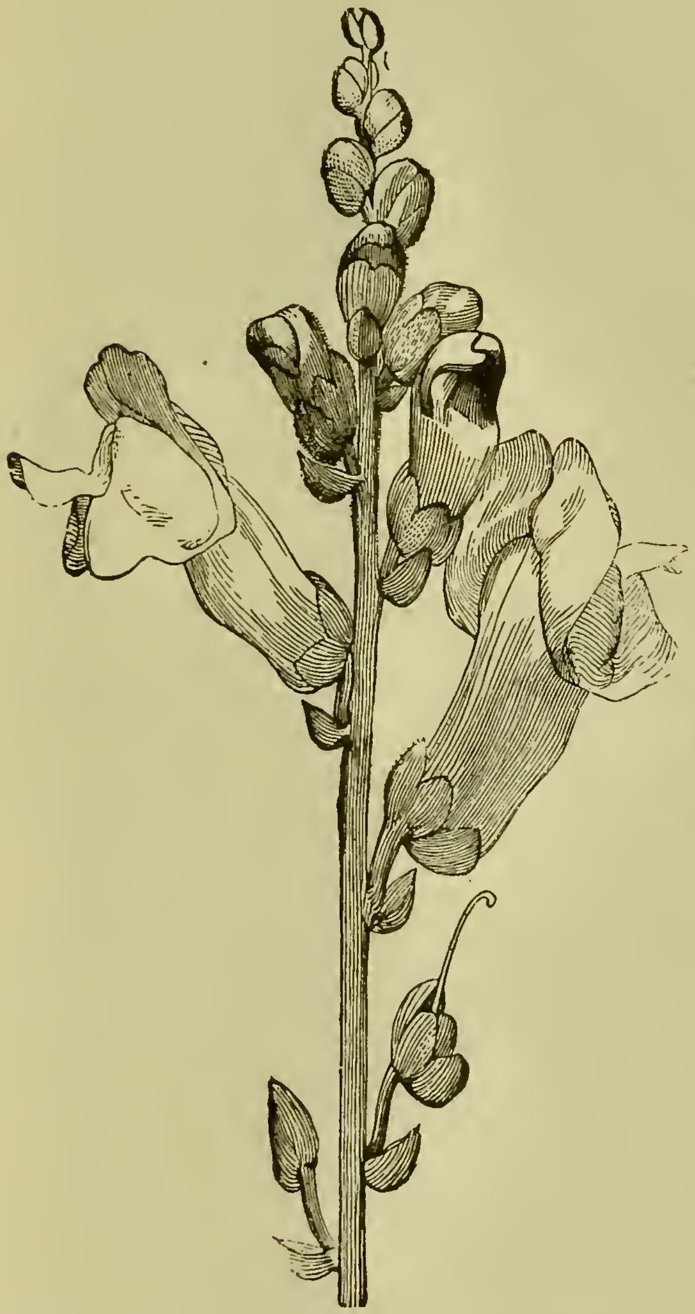


Fig. 486.—*Antirrhinum majus* (natural size).

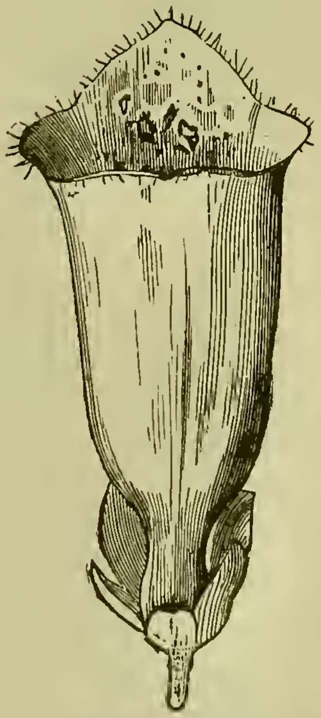


Fig. 488.—Flower of foxglove, *Digitalis purpurea* (natural size).

Order I. Scrophulariaceæ. (Figs. 486–488.) Mostly herbaceous plants, with alternate, opposite, or verticillate exstipulate leaves. Calyx and corolla bilabiate, rarely nearly regular, and 4- or 5-cleft; stamens usually four and didynamous, less often two, as in *Veronica* ; ovary superior, and generally surrounded by a disc, syncarpous and bilocular, with a large number of anatropous ovules attached to an axile placenta divided by the dissepiment. Fruit capsular, rarely baccate ; seeds with endosperm and straight embryo (see Figs. 249 and 297, pp. 130, 144). [The genera are very numerous, and include *Salpiglossis, Schizanthus, Calceolaria, Linaria, Antirrhinum, Maurandia, Lophospermum, Paulownia, Scrophularia, Penstemon, Mimulus, Gratiola, Digitalis, Veronica, Bartsia, Euphrasia, Melampyrum, Rhinanthus, Pedicularis, Verbascum.*] The most important medicinal species is the foxglove, *Digitalis purpurea* ; the leaves of *Gratiola officinalis* are also officinal. A large number of genera are cultivated in gardens for the beauty of their flowers. Many species are root-parasites.

[To this cohort belong also the orders *Utriculariaceæ* (*Utricularia, Pinguicula*); *Orobanchaceæ* (*Orobanche, Lathræa*); *Gesneraceæ* (*Gesnera, Gloxinia, Achimenes, Columnea, Cyrtandra*); *Bignoniaceæ* (*Bignonia, Catalpa, Tecoma, Eccremocarpus*); *Acanthaceæ* (*Ruellia, Goldfussia, Acanthus, Justicia, Adhatoda*) ; *Sesamaceæ* (*Sesamum, Craniolaria, Martynia, Pedalium*).

Cohort II. LAMIALES. Perianth usually bilabiate, rarely nearly or quite regular, hypogynous ; stamens fewer than the corolla-lobes, rarely as many, unequal, usually four and didynamous, rarely two ; ovary 2-4-locular ; style simple ; stigmas one or two ; ovules solitary in each loculus, very rarely two or more ; fruit an indehiscent drupe, or composed of two or four nucules. Herbs, shrubs, or trees, with exstipulate leaves.]

Order I. LABIATÆ. (Figs. 489-492.) Herbaceous or suffruticose plants, usually with square stem and opposite (decussate) or verticillate exstipulate leaves. The flowers are arranged in compact cymes (*verticillasters*) in the axils of the leaves ; and the separate inflorescences are often so crowded as to give to the whole the appearance of a compound spike. The tubular, usually bilabiate, calyx is persistent ; the corolla usually ringent and bilabiate, rarely regular ; in the former case the upper lip consists of two, the lower lip of three teeth (petals); the structure of the bilabiate calyx being the reverse. Stamens rarely two, usually four, of two unequal lengths (*didynamous*) ; but the anthers are not always perfectly developed, sometimes consisting of one lobe only, the other lobe being barren, as in *Salvia* (Fig. 269, p. 138). The mode of dehiscence of the anthers also varies ; in *Galeopsis* it is transverse. The style is *gynobasic*, or rises from the base of the deeply four-lobed ovary, which is placed on an inferior disc ; each division of the ovary contains only a single ovule, with its micropyle directed downwards. Fruit

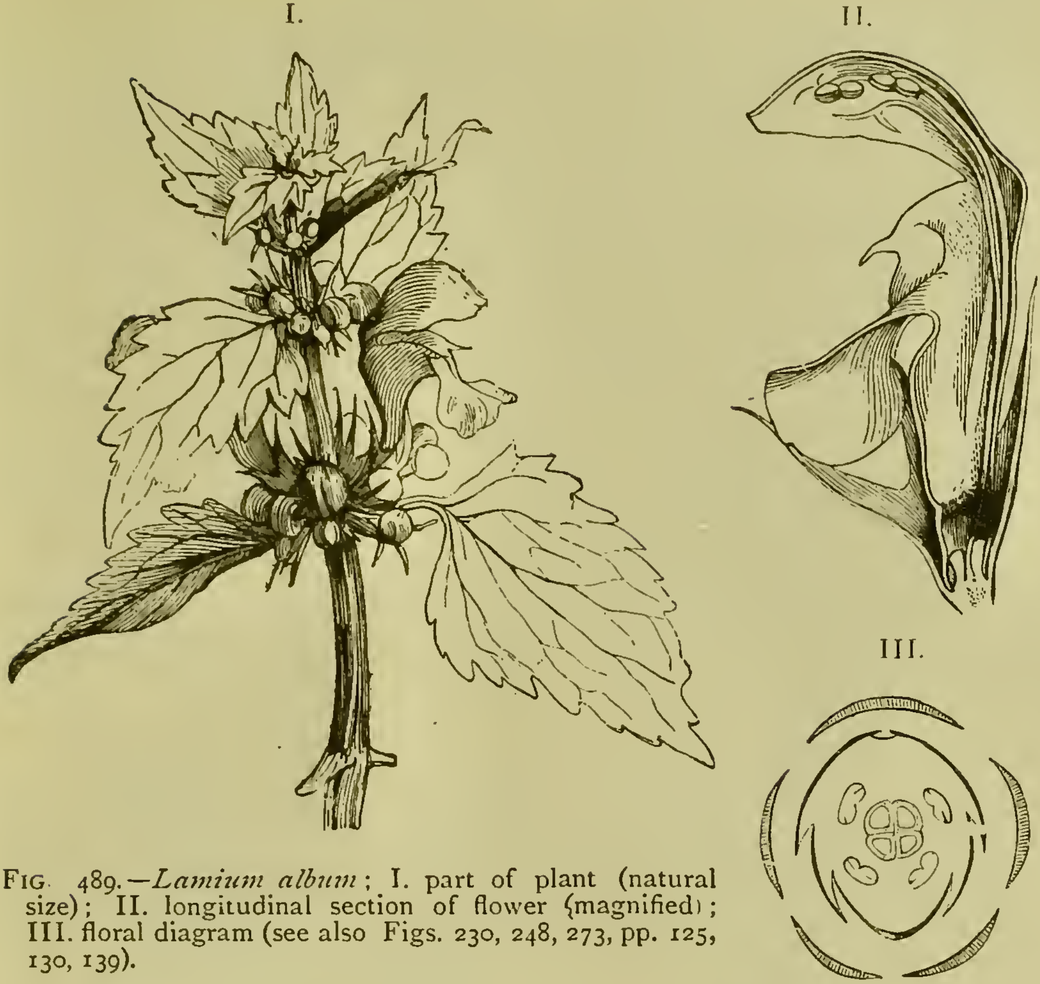


FIG. 489.—*Lamium album*; I. part of plant (natural size); II. longitudinal section of flower (magnified); III. floral diagram (see also Figs. 230, 248, 273, pp. 125, 130, 139).

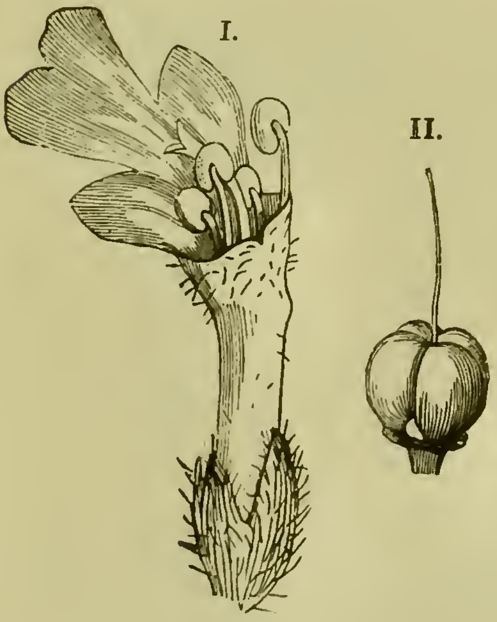


FIG. 490.—*Ajuga reptans*; I. flower; II. carcerulus (magnified).

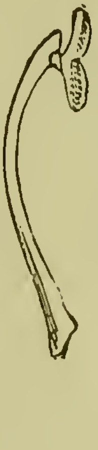


FIG. 491.—Stamen of *Prunella* (magnified).

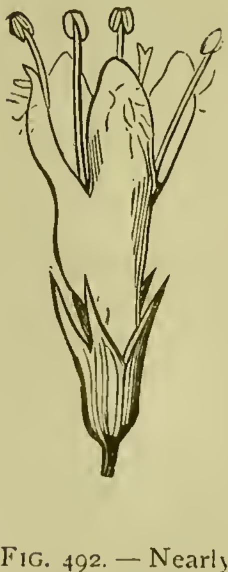


FIG. 492.—Nearly regular flower of peppermint, *Mentha piperita* (magnified).

enclosed in the base of the calyx, and consisting of four *nucules*, each containing a single seed. [Among the numerous genera of this large and important order are *Coleus*, *Lavandula*, *Mentha*, *Origanum*, *Thymus*, *Calamintha*, *Melissa*, *Nepeta*, *Prunella*, *Scutellaria*, *Melittis*, *Marrubium*, *Stachys*, *Lamium*, *Ballota*, *Phlomis*, *Galeopsis*, *Teucrium*, *Ajuga*, *Salvia*.] The plants belonging to it abound in volatile oils contained in special glands, and a large number are consequently officinal; as *Mentha piperita* peppermint, *M. crispa* curled mint, *Lavandula angustifolia* lavender, *Thymus serpyllum* and *vulgaris* the wild and garden thymes, *Rosmarinus officinalis* rosemary, *Ocymum basilicum* basil thyme, *Origanum Majorana* and *vulgare* marjoram, &c. *Salvia officinalis* is valuable on account of the large quantity of tannin contained in it; *Plectranthus graveolens* of the Mascarene Islands is the source of patchouli.

[The only other important order of the cohort is *Verbenaceæ*, which includes the genera *Verbena*, *Lantana*, *Tectona*, *Clerodendron*, *Vitex*, *Avicennia*.

SECTION II. *Flowers usually regular.*

Cohort III. POLEMONIALES. Corolla gamopetalous, hypogynous, regular or oblique; stamens as many as the corolla-lobes, epipetalous, equal or unequal, often exserted; ovary 1-5-locular, syncarpous (rarely apocarpous); seeds very numerous, or only one to two in each loculus. Herbs, rarely shrubs or trees, with exstipulate, alternate or geminate, rarely opposite, leaves.]

Order I. SOLANACEÆ. (Figs. 493-497.) Herbaceous or suffruticose plants with alternate, in the upper part geminate, leaves, one of each pair being always smaller than the other. Calyx usually 5-partite and persistent; corolla regular, deciduous, folded in the bud, and 4- or 5-partite; stamens equal in number to the corolla-lobes; ovary usually bilocular, or almost 4-locular by false septa, rarely 3- or 5-locular. The numerous seeds have an abundant fleshy endosperm; fruit a capsule or berry. [Among the more important genera are *Nicotiana*, *Petunia*, *Datura*, *Hyoscyamus*, *Nicandra*, *Lycopersicum*, *Lycium*, *Physalis*, *Atropa*, *Capsicum*, *Mandragora*, *Solanum*, *Nolana*.] The useful and officinal plants belonging to it are numerous, including the potato *Solanum tuberosum*, *S. dulcamara* the bitter-sweet, *Lycopersicum esculentum* of the East Indies the tomato, *Capsicum annuum* of the West Indies or Cayenne pepper, *Nicotiana Tabacum* tobacco, *Atropa Belladonna* the deadly nightshade, *Hyoscyamus niger* the henbane, *Datura Stramonium* the thorn-apple, *Physalis Alkekengi* the winter cherry, &c.

This cohort includes also the following orders :—*Hydrophyllaceæ* (*Hydrophyllum, Nemophila, Eutoca*); *Polemoniaceæ* (*Phlox, Collomia, Gillia, Polemonium, Cobæa*); *Convolvulaceæ* (*Quamoclit, Batatas, Pharbitis, Ipomœa, Convolvulus, Evolvulus, Porana, Cuscuta*); and *Borragineæ* (*Heliotropium, Cerinthe, Echium, Borrago, Symphytum, Anchusa, Lycopsis, Lithospermum, Pulmonaria, Myosotis, Cynoglossum, Omphalodes*).

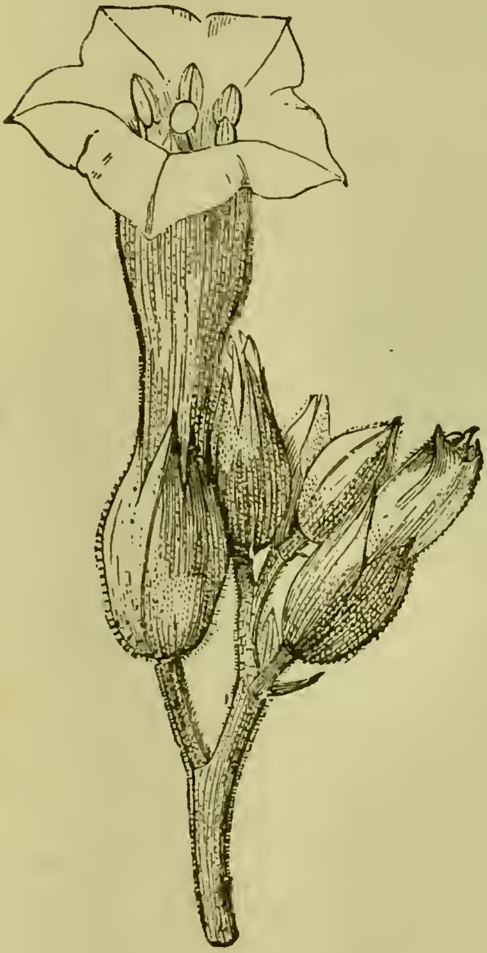


FIG. 493.—Flower of tobacco, *Nicotiana Tabacum* (natural size).

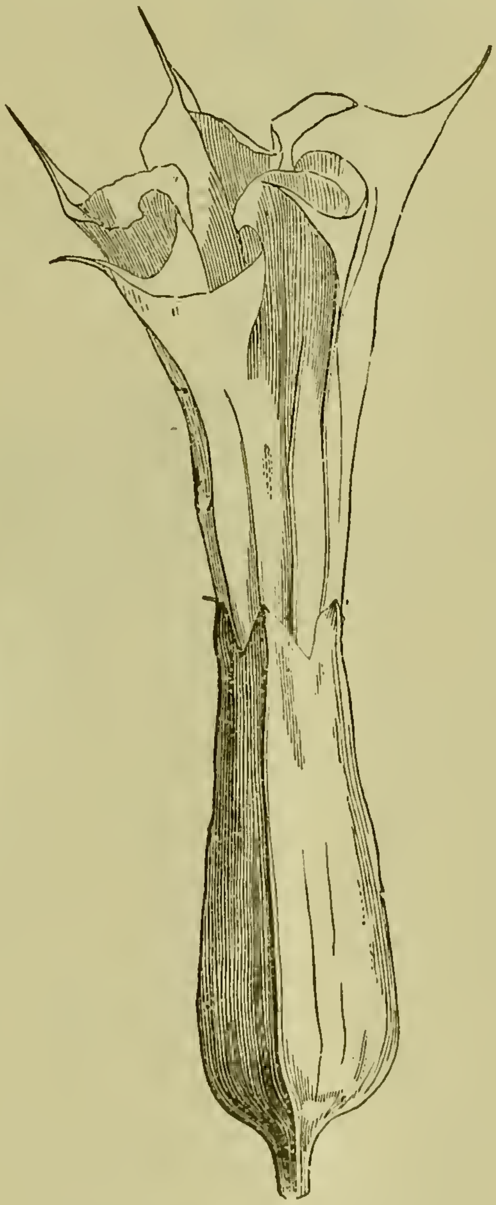


FIG. 494.—Flower of thorn-apple, *Datura Stramonium* (natural size). See Fig. 310, p. 150.

Cohort IV. GENTIANALES. Corolla gamopetalous or rarely nearly apopetalous, hypogynous, stamens same in number as corolla-lobes or

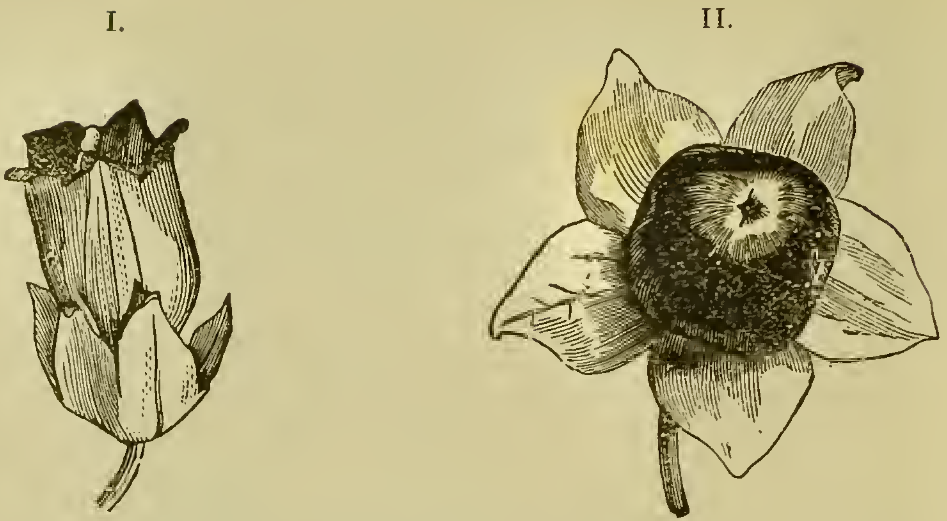


FIG. 495.—Deadly nightshade, *Atropa Belladonna* ; I. flower ; II fruit (natural size).

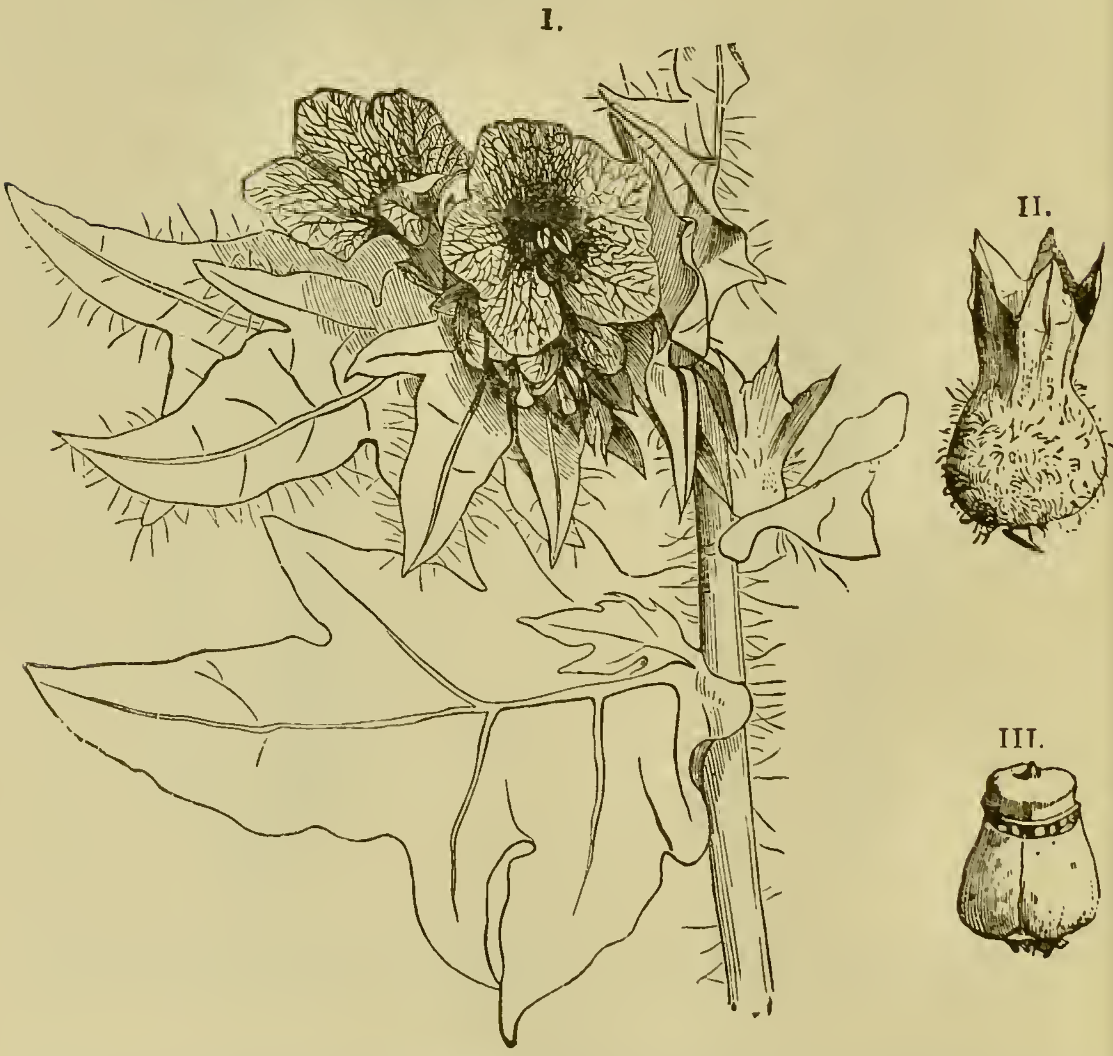


FIG. 496.—Henbane, *Hyoscyamus niger* ; I. part of plant ; II. capsule surrounded by the accrescent calyx ; III. capsule (pyxis) (natural size).

fewer, epipetalous and usually included in corolla-tube ; ovary usually syncarpous and bilocular. Herbs, shrubs, or trees, almost always with opposite or verticillate exstipulate leaves. Orders:— *Oleaceæ* (*Jasminum*, *Olea*, *Ligustrum*, *Phillyrea*, *Fraxinus*, *Syringa*, *Forsythia*); *Apocynaceæ* (*Allamanda*, *Tabernæmontana*, *Vinca*, *Apocynum*, *Nerium*); *Asclepiadeæ* (*Vincetoxicum*, *Cynanchum*, *Asclepias*, *Stephanotis*, *Hoya*, *Stapelia*); *Loganiaceæ* (*Logania*, *Spigelia*, *Strychnos*) ; *Gentianaceæ* (*Erythræa*, *Chlora*, *Gentiana*, *Villarsia*, *Menyanthes*, *Limnanthemum*).

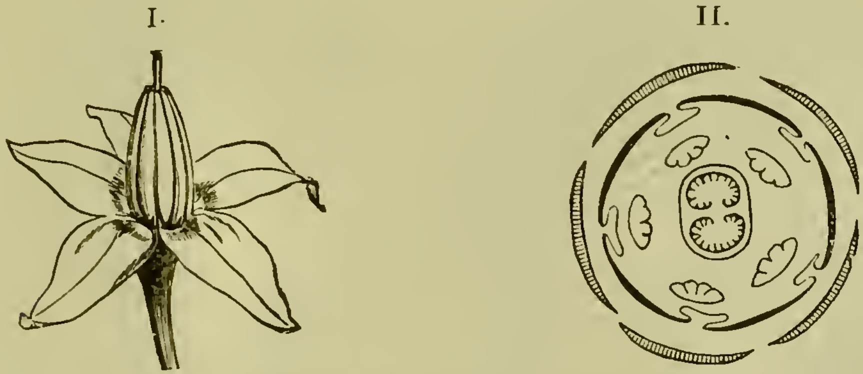


FIG. 497.—I. Flower of *Solanum Dulcamara* (magnified) ; II. Floral diagram of potato *Solanaceæ*).

Cohort V. EBENALES. Corolla gamopetalous or apopetalous, hypogynous or epigynous, rarely perigynous ; stamens usually many more than the corolla-lobes, or if equal in number usually alternate with them ; ovary 2- or multi-locular ; ovules usually few ; fruit rarely capsular. Shrubs or trees, with alternate exstipulate leaves. Principal orders :—*Ebenaceæ* (*Diospyros*) ; *Styraceæ* (*Symplocos*, *Styrax*, *Halesia*).

Cohort VI. PRIMULALES. Corolla regular, hypogynous, rarely epigynous, gamopetalous, rarely apopetalous ; stamens equal in number to corolla-lobes and opposite to them, or if more numerous one series always opposite, hypogynous or epipetalous ; ovary unilocular, with free central placentation. Herbs or shrubs, rarely trees, with exstipulate usually alternate leaves.

Order I. PRIMULACEÆ. (Figs. 138, 298, 306, 311.) Characters essentially those of the cohort. Principal genera:—*Soldanella*, *Cyclamen*, *Lysimachia*, *Primula*, *Anagallis*, *Hottonia*. Other orders :—*Plumbagineæ* (*Plumbago*, *Armeria*, *Statice*) ; *Myrsinaceæ* (*Myrsine*, *Ardisia*).

Cohort VII. ERICALES. Corolla hypogynous or rarely epigynous, gamopetalous or rarely apopetalous ; stamens as many or twice as many as corolla-lobes, hypogynous or epipetalous ; ovary uni- or multi-locular ; ovules one or many ; stigma simple, entire or lobed ; seeds minute. Herbs, shrubs, or trees, often with heath-like leaves, or sometimes parasitic. Orders:—*Ericaceæ* (*Arbutus*, *Gaultheria*, *Andromeda*, *Erica*, *Calluna*, *Rhodora*, *Phyllodoce*, *Ledum*, *Kalmia*, *Azalea*, *Rhododendron*, *Epigæa*, *Clethra*); *Monotropaceæ* (*Monotropa*, *Lathræa*); *Vacciniaceæ* (*Vaccinium*, *Oxycoccus*); *Epacrideæ* (*Epacris*); *Pyrolaceæ* (*Pyrola*).

SUB-DIVISION II. *Epigynous; ovary inferior.*

Cohort VIII. CAMPANALES. Flowers usually irregular, rarely unisexual or collected into involucrate capitula ; stamens as many as corolla-lobes or fewer ; ovary 2–6-rarely uni-locular ; style simple ; stigma often enveloped in a sheath; ovules numerous, rarely solitary. Herbs or rarely shrubs, with exstipulate leaves and often a milky juice. Principal order : *Campanulaceæ* (*Phyteuma*, *Jasione*, *Specularia*, *Campanula*, *Clintonia*, *Lobelia*).

Cohort IX. ASTERALES. Flowers regular or irregular, often unisexual and collected into involucrate capitula ; stamens as many as corolla-lobes, rarely fewer, epipetalous ; ovary uni-locular, ovule solitary, (or rarely 2–3-locular, all but one then barren). Herbs or shrubs, rarely trees, with exstipulate leaves ; calyx-limb usually reduced to a pappus, or absent. (Figs. 498–503.)]

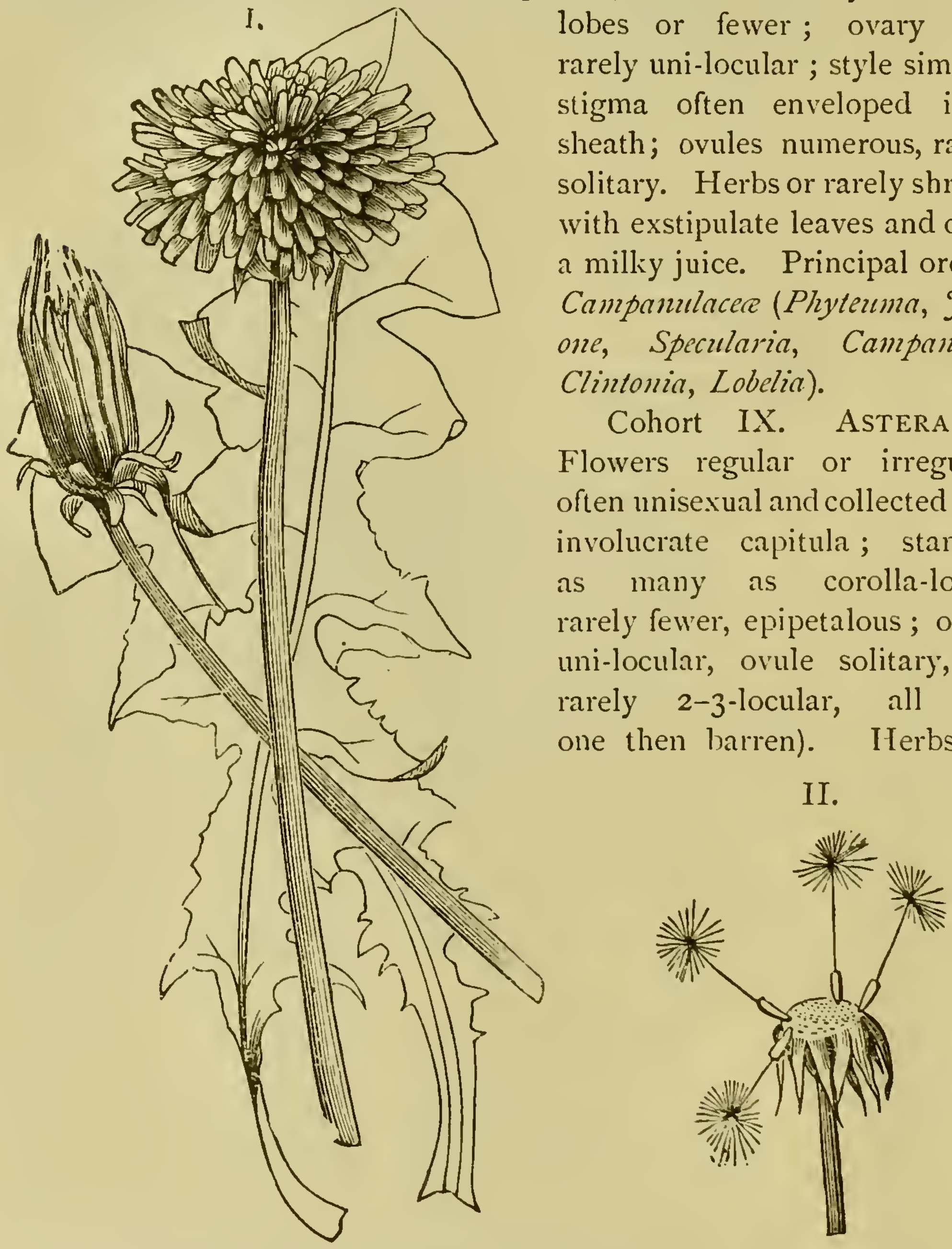


FIG. 498.—Dandelion, *Taraxacum officinale* : I. entire plant (natural size) ; II. receptacle with fruits (magnified). (See also Figs. 213, 214, 217, 218, 219).

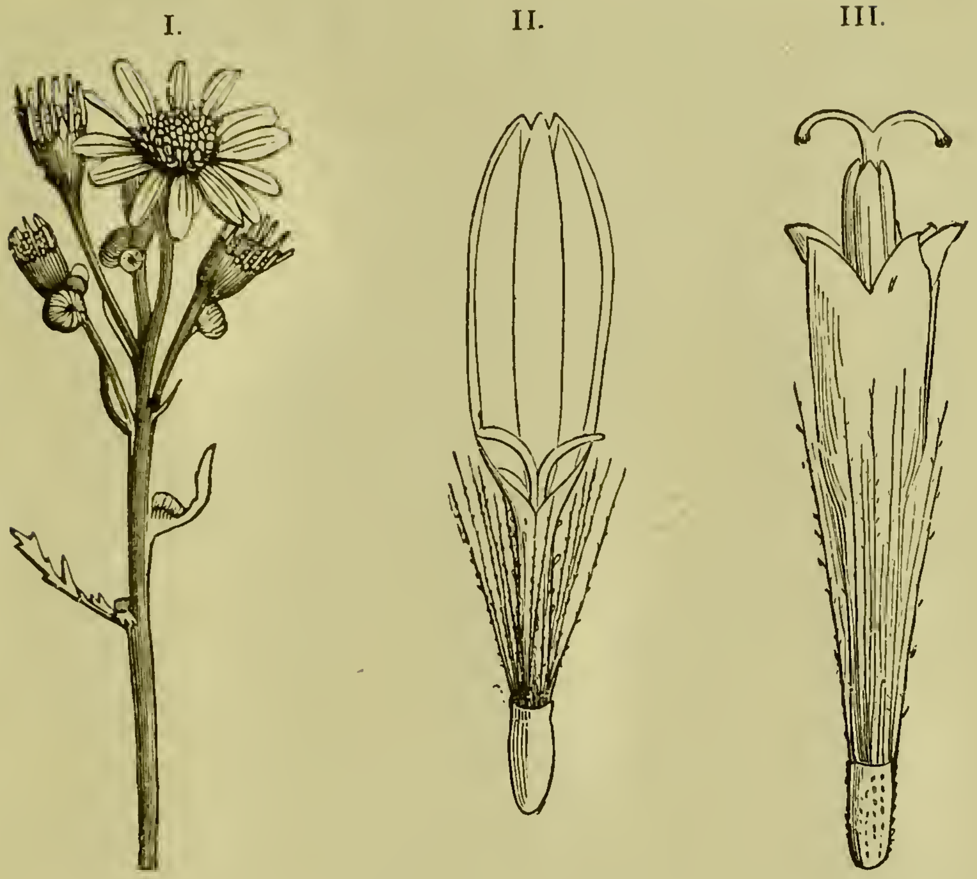


FIG. 499.—*Senecio Jacobæa* ; I. inflorescence (natural size) ; II. ligulate flower ; II. tubular flower (magnified).

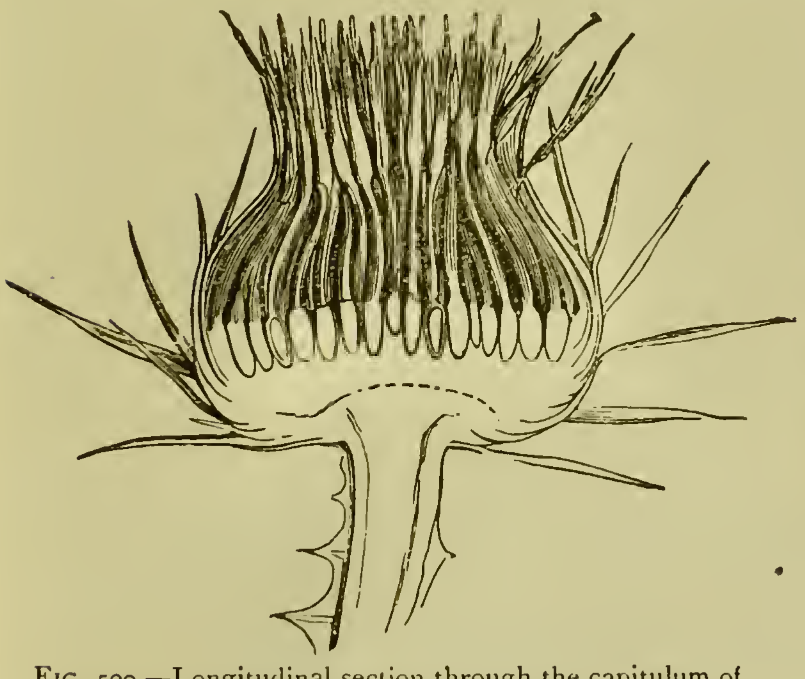


FIG. 500.—Longitudinal section through the capitulum of *Onorpordon acanthium* (natural size).

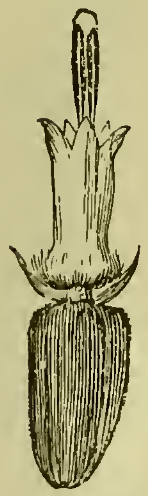


FIG. 501.—Tubular flower of sunflower, *Helianthus annuus*, with inferior ovary (magnified).

Order I. COMPOSITÆ. This order is not only one of the largest, but one of the best characterised and most natural in the vegetable kingdom. It numbers about twelve thousand species distributed over the whole surface of the globe. The species are herbaceous, rarely shrubby, and often (Liguliflorœ) containing a milky latex ; the leaves are exstipulate and usually alternate. The flowers are hermaphrodite, male, female, or neuter (containing neither stamens nor pistil). They are placed on a common broadly expanded receptacle, and are crowded into a capitulum, and surrounded by a *general involucre* of densely crowded bracts. The individual flowers are usually situated in the axils of small bracts, which are called *paleœ*, and the receptacle is then said to be *paleaceous* ; when these are absent it is *naked.* Rarely each flower has a *special involucel.* The calyx consists of an epigynous tube, the free margin of which developes after the withering of the flower, sometimes remaining membranous and entire, but usually transformed into bristles, hairs, scales, or a silky *pappus* (see p. 127). The corolla is always gamopetalous, and is usually 5- but sometimes 4- or 3-cleft, is either *tubular* and regular, or *bilabiate,* having in the latter case two divisions in the upper and three in the lower lip, or *ligulate.* The five stamens are attached to the corolla-tube and are alternate with its teeth ; their filaments are free, but their anthers coherent into a tube (*syngenesious*), always furnished at the apex with one, sometimes at the base with two appendages. The ovary is inferior and unilocular, and contains a single erect ovule. The style branches in the upper part into two arms, and is usually furnished with collecting hairs which act like a brush in collecting the pollen. The fruit is a *cypsela* containing a single seed without endosperm. The flowers (florets) of the central part of the capitulum are often of a different structure and colour from those of the margin ; and the two kinds are hence often called *florets of the disc* and *florets of the ray.*

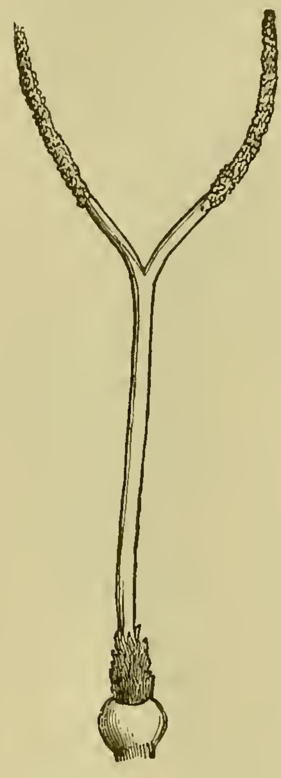


FIG. 502. — Pistil of *Eupatorium* (magnified).

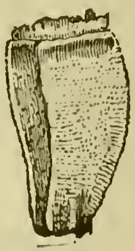


FIG. 503. — Fruit of chicory, *Cichorium Intybus*, with coronate pappus (magnified).

[The order is divided into three suborders, as follows :—

1. *Liguliflorœ.* Flowers all hermaphrodite and ligulate ; style with

filiform branches, pubescent; stigmatic bands separate, and not half as long as the branches of the style. Herbs with alternate leaves and a milky latex :—*Catananche*, *Cichorium*, *Picris*, *Crepis*, *Hieracium*, *Hypochæris*, *Leontodon*, *Taraxacum*, *Lactuca*, *Sonchus*, *Tragopogon*, *Scorzonera*, *Scolymus*.

2. *Labiatifloræ.* Corolla of the hermaphrodite flowers usually bilabiate; of the male and female flowers ligulate or bilabiate :—*Mutisia*.

3. *Tubulifloræ.* Flowers sometimes all tubular, regular and hermaphrodite, rarely irregular and neuter, sometimes those of the disc tubular, of the ray ligulate, the former hermaphrodite, the latter female or neuter :—*Vernonia*, *Eupatorium*, *Mikania*, *Solidago*, *Bellis*, *Aster*, *Erigeron*, *Conyza*, *Filago*, *Gnaphalium*, *Helichrysum*, *Inula*, *Pulicaria*, *Silphium*, *Xanthium*, *Zinnia*, *Rudbeckia*, *Helianthus*, *Coreopsis*, *Dahlia*, *Bidens*, *Achillea*, *Anthemis*, *Chrysanthemum*, *Matricaria*, *Tanacetum*, *Artemisia*, *Tussilago*, *Petasites*, *Arnica*, *Doronicum*, *Cineraria*, *Senecio*, *Calendula*, *Echinops*, *Carlina*, *Carduus*, *Cnicus*, *Onopordon*, *Cynara*, *Centaurea*, *Carthamus*.]

Since the Compositæ abound in latex, bitter principles, and volatile oils, a large number of species are officinal, while others are of technical or economical value. Among the most important are the following :—the flowers of *Arnica montana*; chamomile flowers from *Matricaria Chamomilla* and *Anthemis nobilis*; wormwood from *Artemisia chinensis* and *Absinthium*; coltsfoot from *Tussilago Farfara*; the leaves of *Cnicus benedictus*; the roots of *Lappa tomentosa*, *officinalis*, and *minor*, and *Anacyclus officinarum*; elecampane from *Inula Helenium*; taraxacum from *Taraxacum officinale*; absinthe from *Artemisia Absinthium*; the ethereal oil of the tansy, *Tanacetum vulgare*; the dried latex of *Lactuca virosa* and *sativa*. *Mikania Guaco* of Central America is a remedy against snake-bites; the crushed flower-buds of *Pyrethrum carneum* from the Caucasus are used as an insecticide. Among culinary vegetables are the lettuce *Lactuca sativa*, endive *Cichorium Endivia*, tarragon *Artemisia Dracunculus*, chicory *Cichorium Intybus*, scorzonera *Scorzonera hispanica*, the Jerusalem artichoke *Helianthus tuberosus*, and the artichoke *Cynara Scolymus*. The seeds of the sunflower, *Helianthus annuus*, yield a useful oil, as does the fruit of *Madia sativa*; safflower is obtained from the flower-heads of *Carthamus tinctorius*. 'Everlastings' are the dried flower-heads of species of *Helichrysum* and *Gnaphalium*, and *G. leontopodium* is the 'Edelweiss' of the Alps. The common marigold is a species of *Calendula*.

[To this cohort belong also *Valerianaceæ* (*Valeriana*, *Centranthus*, *Fedia*); and *Dipsacaceæ* (*Dipsacus*, *Knautia*, *Scabiosa*).

Cohort X. RUBIALES. Flowers regular or irregular ; stamens as many as corolla-lobes, epipetalous ; ovary 2- or multi-locular ; ovules solitary or numerous ; seeds with or very rarely without endosperm. Shrubs or trees rarely herbs, with opposite or verticillate often stipulate leaves ; calyx never pappose.

Order 1. RUBIACEÆ. (Figs. 504, 505.) Trees or shrubs, rarely herbs, with simple, entire, opposite leaves.] The stipules are in many genera so similar to the true leaves as to give the appearance of a spurious whorl. The stamens are equal in number to the corolla-lobes and alternate with them ; the ovary bilocular, the seeds solitary or rarely two in each loculus, or multilocular and the seeds several in each division.

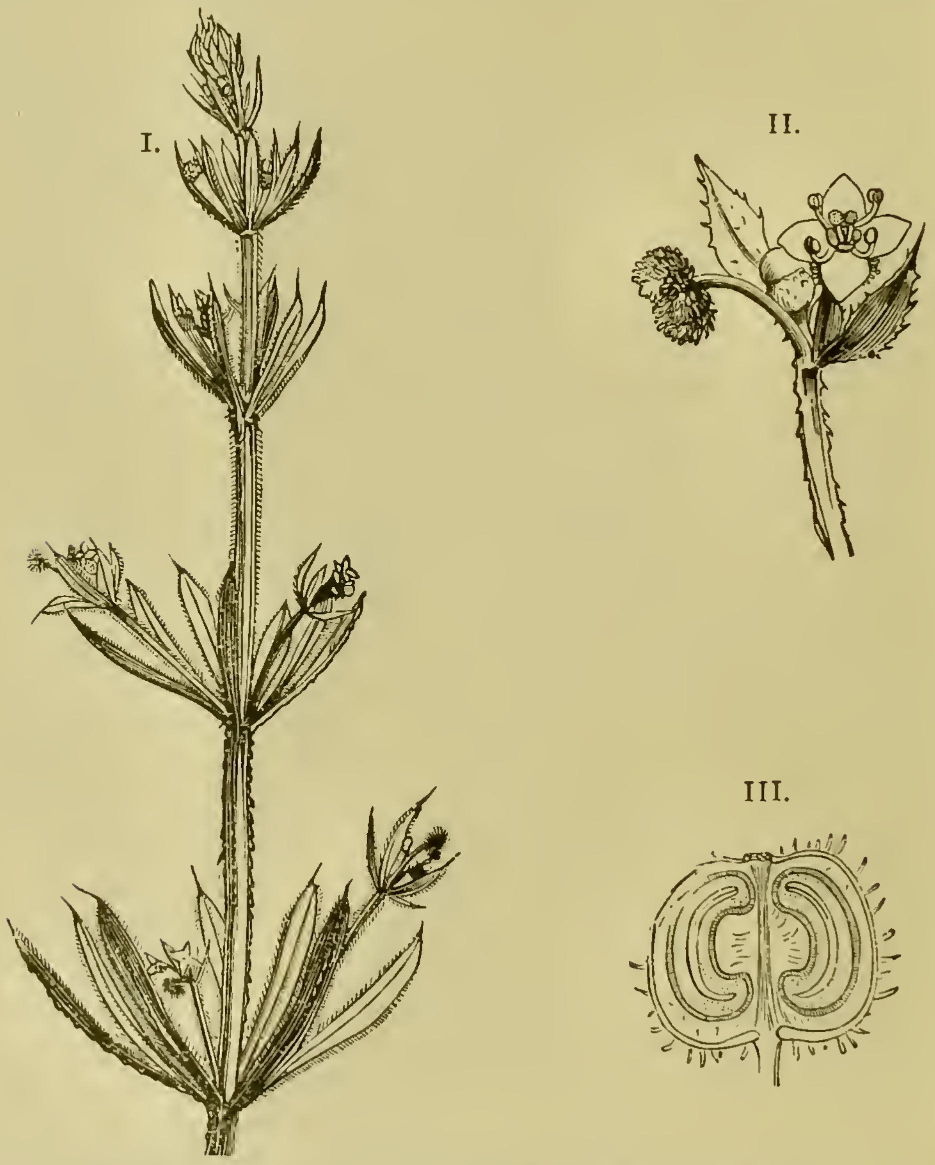


FIG. 504.—*Galium Aparine* ; I. part of plant (natural size) ; II. flower and fruit (magnified) ; III. longitudinal section through fruit (greatly magnified).

The fruit is a drupe, berry, capsule, or achene, or is sometimes dehiscent; the endosperm large and horny, as in the coffee-berry, or fleshy. [The order is a very large one, and is divided into a large number of tribes.

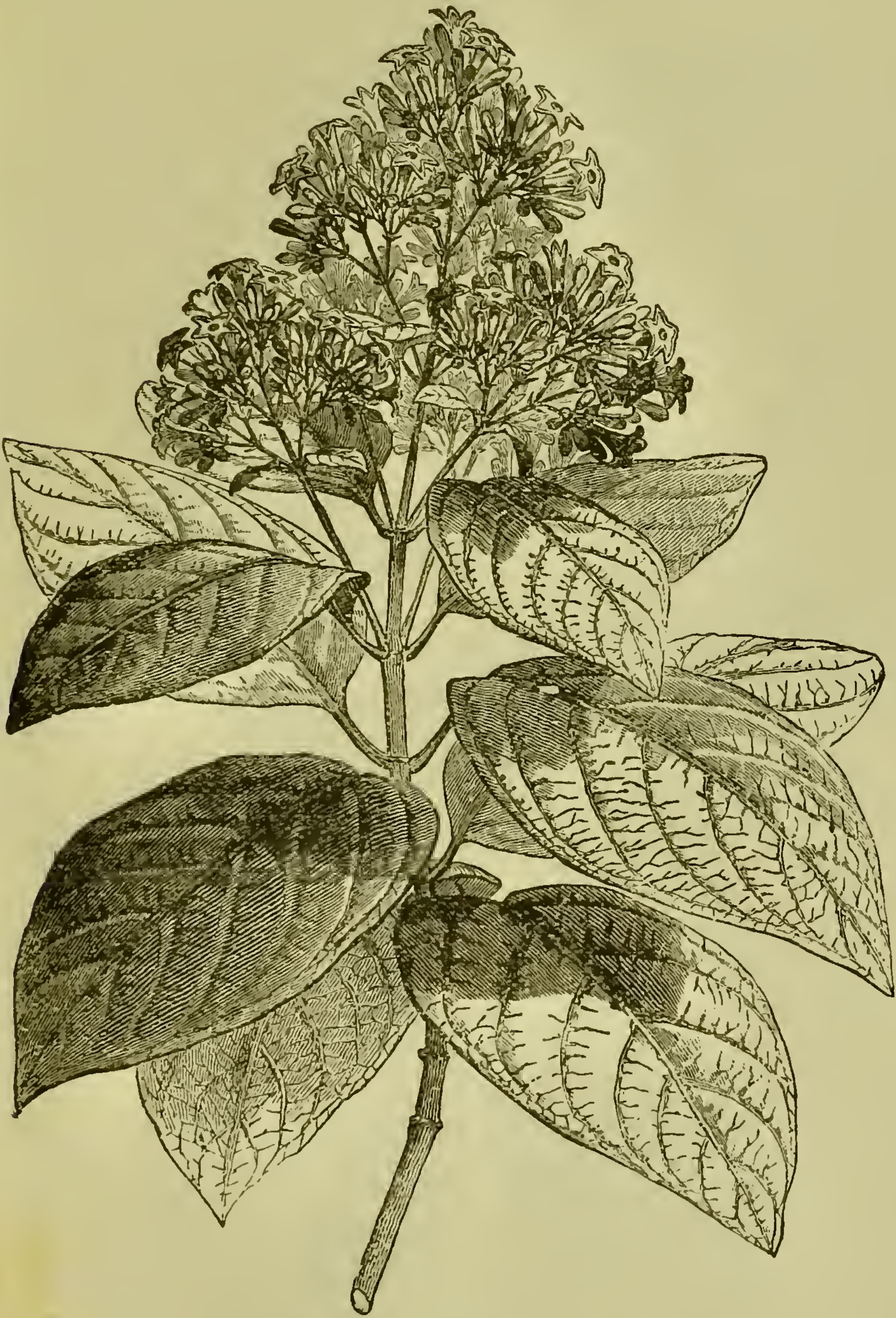


FIG. 505.—Peruvian Bark, *Cinchona condaminea* (reduced).

The suborders *Stellatæ*, *Cinchoneæ*, and *Coffeeæ* of some authors are distinguished by the first having the leaves in apparent whorls from the interpetiolar stipules; the second has opposite leaves and a multilocular ovary with numerous seeds; the third opposite leaves and a bilocular two-seeded ovary. The European species all belong to the *Stellatæ*, and are herbaceous. Among the more important genera of the order are the following:—*Uncaria*, *Nauclea*, *Cinchona*, *Cascarilla*, *Condaminea*, *Mussænda*, *Gardenia*, *Ixora*, *Coffea*, *Cephaëlis*, *Spermacoce*, *Rubia*, *Galium*, *Asperula*.] It includes plants of very great medicinal and economical value. Peruvian bark and quinine are obtained from various species of *Cinchona*, all natives of central and western South America; the best kind is the product of *C. Calisaya* of Bolivia; others of *C. glandulifera* of Peru, *C. condaminea* of northern Peru and southern Ecuador, and *C. succirubra* of Chimborazo. It is cultivated with success in Java and India. *Coffea arabica*, the source of coffee, grows in Arabia and the East and West Indies. Ipecacuanha is the root of *Cephaëlis Ipecacuanha* of Brazil. Catechu is the product of the East Indian *Uncaria Gambir*. The important dye known as madder is obtained from the root of *Rubia tinctorum*.

[The only other order belonging to this cohort is *Caprifoliaceæ* (*Leycesteria*, *Symphoricarpus*, *Linnæa*, *Weigelia*, *Lonicera*, *Viburnum*, *Sambucus*).

DIVISION III. CALYCIFLORÆ.—*Sepals connate, rarely free, often adnate to the ovary; petals distinct, in a single whorl, perigynous or epigynous; disc adnate to the base of the calyx, rarely tumid or raised into a torus or gynophore; stamens perigynous or epigynous, usually inserted in or beneath the outer margin of the disc; ovary frequently inferior.*

Cohort I. UMBELLALES.—Flowers usually hermaphrodite; stamens usually definite; ovary inferior, 1-, 2-, or multi-locular; ovules solitary, pendulous; styles free or connate at the base; ovules with the coats confluent with the nucleus; seeds albuminous; embryo usually minute; flowers generally in umbels.]

Order 1. UMBELLIFERÆ. (Figs. 506–513.) Herbs, rarely shrubs, with round or furrowed jointed stem, and alternate usually compound leaves sheathing at the base. The flowers are hermaphrodite [except occasionally the outermost in the umbel], and are arranged in simple or compound umbels, which in some genera are contracted into capitula by the shortening of the axis; the inflorescence is usually surrounded by an involucre consisting of a single whorl of bracts; when this includes the entire inflorescence it is called the *general involucre*; when it includes only a secondary umbel, a partial involucre or *involucel*. The calyx-tube is adherent to the ovary, but with a free five-toothed or entire margin [which is however sometimes almost obsolete]. The petals are five, distinct, entire, emarginate or two-lobed, the outer ones often larger than the inner, or *rayed*; adherent to the calyx and alternate with its teeth. The stamens are five, rolled up in vernation; the ovary usually bi-, rarely

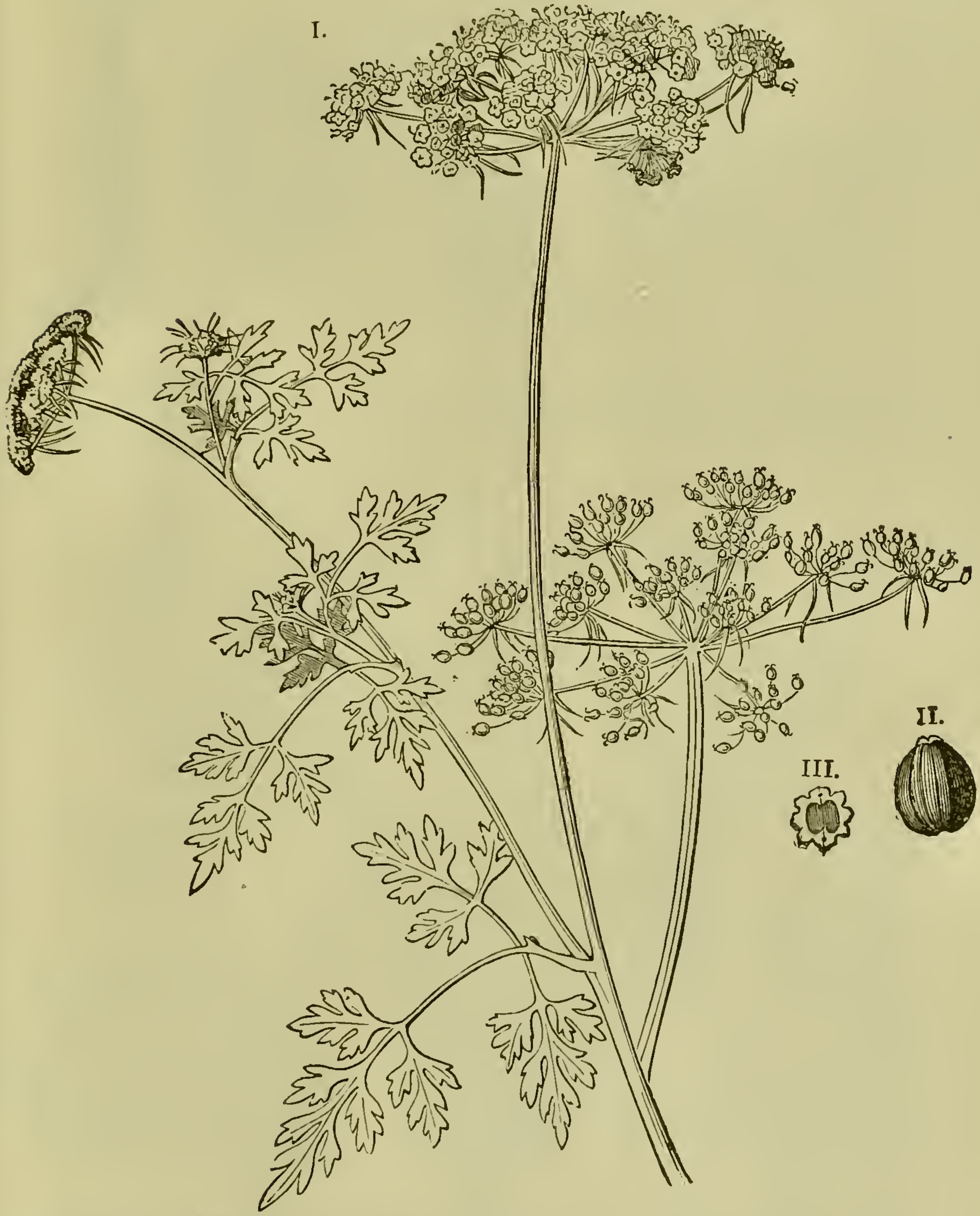


Fig. 506.—I. *Æthusa Cynapium*, fool's parsley (natural size); II. fruit (magnified); III. section of fruit.

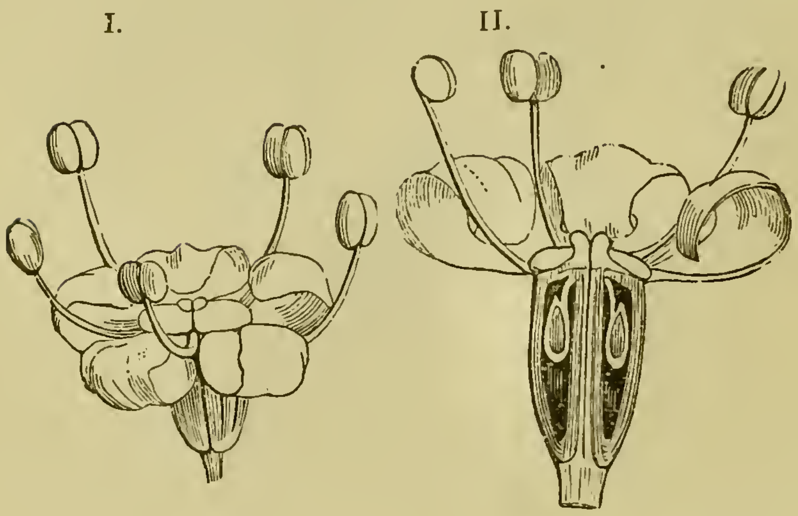


Fig. 507.—Flower of fennel, *Fœniculum officinale*, I. entire ; II. in longitudinal section (magnified).

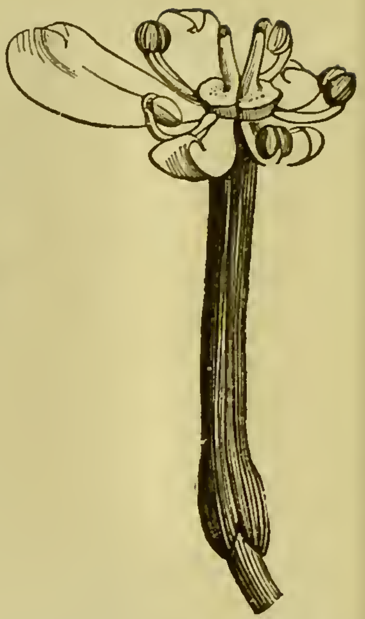


Fig. 508.—Rayed flower of Venus's comb, *Scandix pecten-Veneris* (magnified).

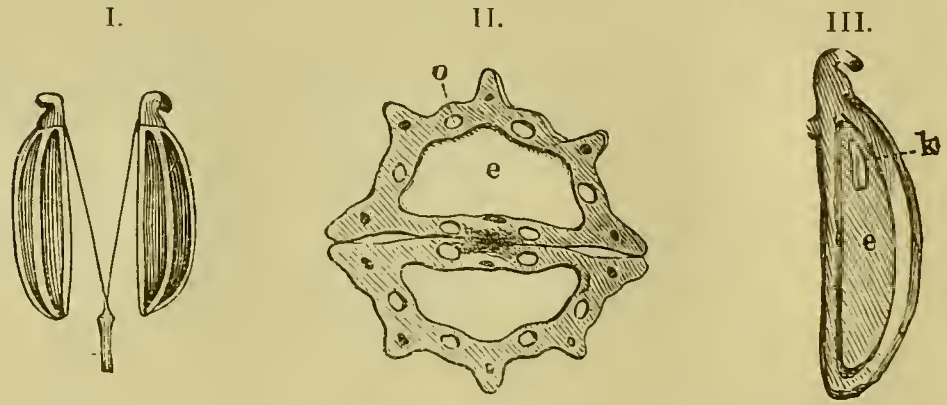


Fig. 509.—I. Fruit of fennel, *Fœniculum officinale* ; II. transverse section, *e* endosperm, *o* vittæ ; III. longitudinal section : *k* embryo (magnified).

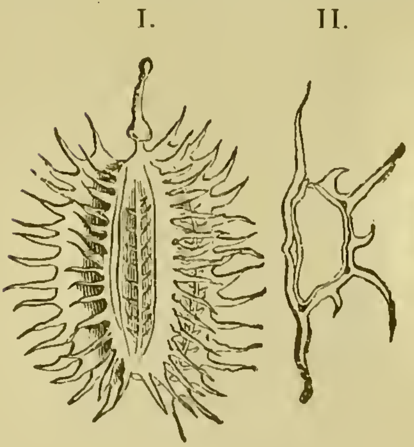


Fig. 510. — I. Fruit of carrot, *Daucus Carota* (Orthospermæ) ; II. transverse section ; the four secondary ridges are conspicuous ; of the primary ridges the two lateral ones are scarcely visible, the median (carina) and intermediate ones are spiny (magnified).

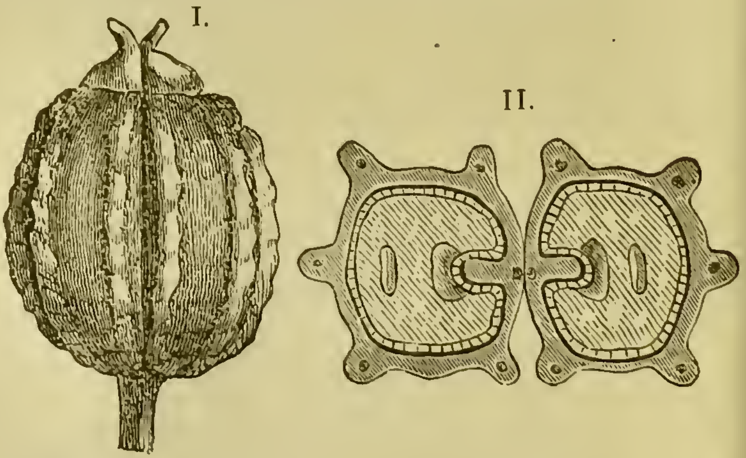


Fig. 511.—I. Fruit of hemlock, *Conium maculatum* (Campylospermæ) ; II transverse section ; part of the embryo is seen in the centre of the endosperm (magnified).

uni-locular, and contains a single pendulous ovule in each loculus. Each of the two styles is expanded at its base into the *disc*, which crowns the apex of the ovary and is termed the *stylopode*. The fruit is a bipartite schizocarp or *cremocarp*, separating from below upwards, two halves (*mericarps*) separating from the columella or *carpophore*, the carpophore itself splitting from the apex halfway down or to the base (Fig. 509).

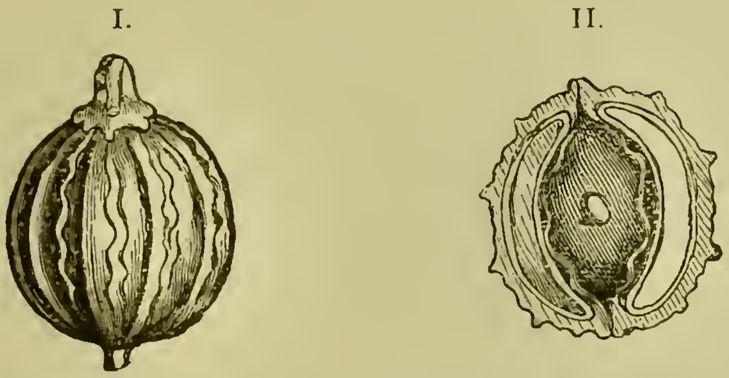


FIG. 512.—I. Fruit of coriander, *Coriandrum sativum* (Cœlospermæ) ; II. transverse section (magnified).

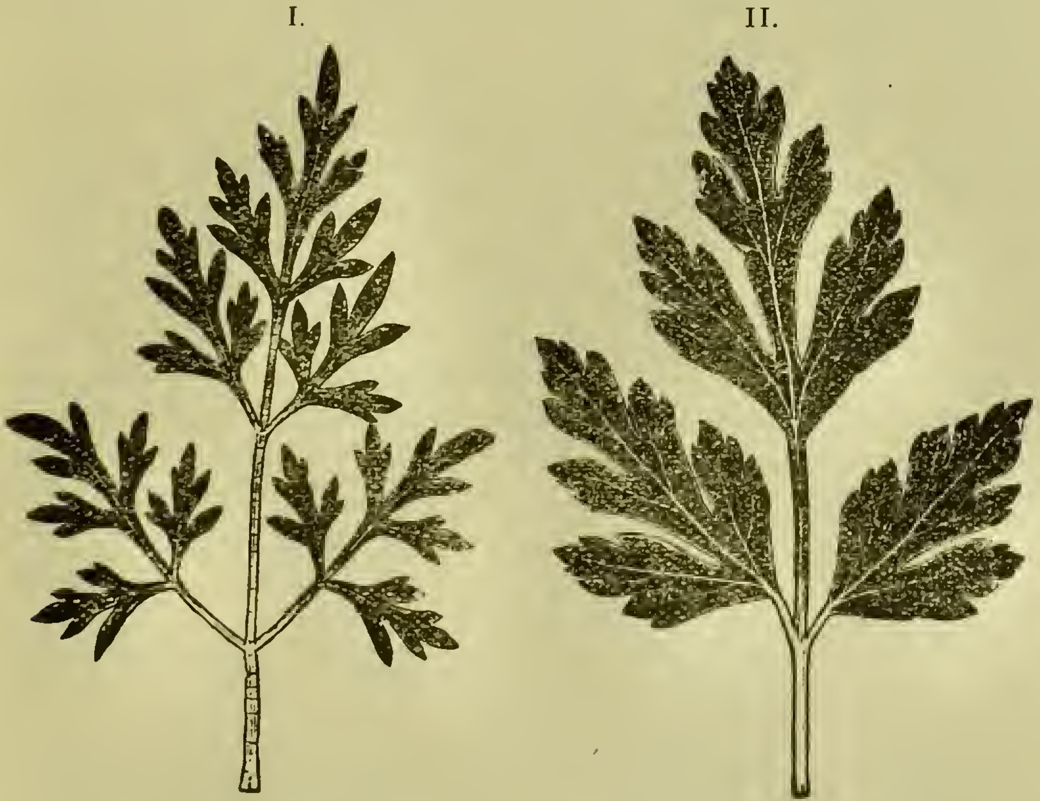


FIG. 513.—I. Leaf of *Æthusa* ; II. leaf of parsley (nature-printed).

The small embryo is enclosed in the apex of a large endosperm. The free and usually convex outer sides of the mericarps, which are attached to one another by their inner surfaces, are termed the back, and each mericarp has five more or less conspicuous longitudinal ridges or *primary juga*, the median of which is the *carina* ; the two outermost are the *marginal* or *lateral* ; those that lie between the *intermediate ridges*. Alternate with the primary are often four *secondary ridges*, which are not unfrequently more strongly developed than the primary ones, but are always at once recognised by their position, the central one or carina being always a primary ridge. The intervals which separate the primary ridges are termed *furrows* ; and beneath their surface are a number of slightly projecting canals or *vittæ* containing a volatile oil, which are usually visible only on making a transverse section. The endosperm is on the ventral side, and is either flat, in the suborder *Orthospermæ*, or less often channelled longitudinally by the incurving of the margins (*Campylospermæ*) ; or hollowed out (*Cœlospermæ*). [Among the very numerous genera belonging to this large and important order are *Hydrocotyle*, *Eryngium*, *Astrantia*, *Sanicula*, *Conium*, *Smyrnium*, *Bupleurum*, *Apium*, *Cicuta*, *Ammi*, *Carum*, *Sium*, *Sison*, *Ægopodium*, *Pimpinella*, *Conopodium*, *Myrrhis*, *Chærophyllum*, *Anthriscus*, *Seseli*, *Fœniculum*, *Crithmum*, *Œnanthe*, *Æthusa*, *Meum*, *Ligusticum*, *Levisticum*, *Angelica*, *Archangelica*, *Ferula*, *Peucedanum*, *Heracleum*, *Opopanax*, *Coriandrum*, *Cuminum*, *Daucus*, *Petroselinum*, *Pastinaca*, *Bunium*, *Anethum*.] The roots contain abundance of resin, and the fruits a volatile oil. Among culinary vegetables are the carrot *Daucus Carota*, chervil *Anthriscus cerefolium*, celery *Apium graveolens*, parsley *Petroselinum sativum*, parsnip *Pastinaca sativa*, fennel *Fœniculum officinale*, &c. Among medicinal products are the caraway *Carum Carui*, coriander *Coriandrum sativum*, water-fennel *Œnanthe Phellandrium*, dill *Anethum graveolens*, anise *Pimpinella Anisum*, pimpinella *Pimpinella Saxifraga*, archangel *Archangelica officinalis*, lovage *Levisticum officinale*, assafœtida *Narthex Assafœtida*, ammoniacum *Dorema ammoniacum*, and galbanum *Galbanum officinale*, the last three from Persia. The following are poisonous :—Hemlock *Conium maculatum*, fool's parsley *Æthusa Cynapium*, dropwort *Œnanthe fistulosa*, water-hemlock *Cicuta virosa*, and wild chervil *Chærophyllum temulum*.

[To the same cohort belong *Araliaceæ* (*Aralia*, *Hedera*, *Panax*); and *Cornaceæ* (*Cornus*, *Benthamia*, *Aucuba*).

Cohort II. FICOIDALES. Flowers regular or nearly so ; ovary syncarpous, inferior half-inferior or superior ; unilocular with parietal placentæ, or 2- to multi-locular with basilar or axile placentæ ; seed albuminous with curved embryo, or exalbuminous with oblique embryo. Succulent herbs. Orders :—*Cactaceæ* (*Melocactus*, *Mamillaria*, *Echino-*

cactus, *Cereus*, *Phyllocactus*, *Epiphyllum*, *Rhipsalis*, *Opuntia*); *Ficoideæ* (*Aizöon*, *Telephium*); *Mesembryanthemaceæ* (*Mesembryanthemum*).

Cohort III. PASSIFLORALES. Flowers usually regular, hermaphrodite or unisexual; ovary usually inferior, syncarpous, unilocular, with parietal placentæ, sometimes 3- or multi-locular by the produced placentæ; styles free or connate. Mostly twining or climbing herbs or shrubs, commonly furnished with tendrils. Principal orders:—*Passifloraceæ* (*Malesherbia*, *Passiflora*, *Tacsonia*, *Modecca*, *Carica*); *Cucurbitaceæ* (*Luffa*, *Momordica*, *Cucumis*, *Citrullus*, *Cucurbita*, *Bryonia*, *Elaterium*, *Sicyos*, *Gynostemma*); *Begoniaceæ* (*Begonia*).

Cohort IV. MYRTALES. Flowers regular or nearly so, usually hermaphrodite; ovary syncarpous, usually inferior; styles united, very rarely free; placentæ axile or apical, rarely basal. Trees, shrubs, or rarely herbs, with simple usually entire leaves.]

Order I. MYRTACEÆ. Trees or shrubs, rarely herbs, usually with opposite exstipulate leaves, which appear punctated by glands containing a volatile oil; flowers solitary in the axils of the leaves; stamens numerous, with the filaments sometimes coherent into one or more bundles; ovary inferior or half-inferior, uni- or multi-locular; the fruit a berry or capsule, generally crowned with the calyx-limb. [Among the more striking genera of this large and important order, chiefly natives of tropical or subtropical countries, are *Callistemon*, *Melaleuca*, *Metrosideros*, *Calothamnus*, *Leptospermum*, *Eucalyptus*, *Psidium*, *Myrtus*, *Pimenta*, *Eugenia*, *Caryophyllus*, *Barringtonia*, *Bertholettia*, *Lecythis*, *Napoleona*.] The flower-buds of *Caryophyllus aromaticus* of the Moluccas and Antilles are the cloves of commerce; other officinal products of the order are cajeput-oil from *Melaleuca minor* of the Moluccas, and kino, the dried sap of *Eucalyptus resinifera* of Australia; *Eugenia Pimenta* of the West Indies is known as allspice. The wood of *Metrosideros vera* of Australia is the hard and valuable iron-wood. Several species of the Australian genus *Eucalyptus* or gum-tree, especially the Tasmanian *E. globulus*, are much cultivated for the rapidity of their growth and the anti-miasmatic properties of their leaves. The fruit of *Psidium pyriferum* is the guava of the West Indies; Brazil nuts are the seeds of *Bertholettia excelsa* of Brazil; the fruits of *Lecythis ollaria* are known as 'monkey-pots.'

The other important orders of the cohort are *Melastomaceæ* (*Melastoma*); *Lythraceæ* (*Lythrum*, *Lagerstrœmia*); *Onagraceæ* (*Epilobium*, *Fuchsia*, *Jussieua*, *Circæa*, *Godetia*, *Clarkia*, *Œnothera*); *Rhizophoraceæ* (*Rhizophora*); *Combretaceæ* (*Quisqualis*, *Combretum*, *Terminalis*).

Cohort V. ROSALES. Flowers usually hermaphrodite, regular or irregular; carpels one or more, usually quite free in the bud, sometimes variously united afterwards with the calyx-tube, or enclosed in the swollen top of the peduncle ; styles usually distinct or only one.]

Order I. LEGUMINOSÆ. Herbs, shrubs, or trees, with stipulate leaves, usually alternate and compound. Calyx either imbricate or valvate in bud, 2-lipped, 5-cleft or 5-toothed, the odd section being below ; very rarely 4-cleft ; petals equal in number to the calyx-teeth, seldom fewer ; stamens usually double as many, often much more numerous. The monocarpellary, unilocular, free, superior ovary develops into a legume or lomentum, bearing on its ventral suture the seeds, which have no or very little endosperm.

This very large and important order is divided into three well-marked suborders, as follows :—

I. *Papilionaceæ.* (Figs. 514-516.) Herbs, shrubs, or trees of very various habit, usually with alternate and compound, pinnate or digitate leaves. The petiole has two stipules, and sometimes each pinna has also a stipella ; the stipules are sometimes transformed into thorns [or tendrils]; and the petiole frequently ends in a tendril. The flowers are seldom solitary, usually collected into spikes, racemes, or umbels, but never in compound inflorescences. The calyx is gamosepalous, 5-toothed, and often 2-lipped ; the corolla attached to its base, and irregular, 5-leaved, and *papilionaceous.* The two inferior petals are mostly more or less coherent and form the *keel* or *carina* (see Fig. 253, p. 132), the two lateral ones being the *wings* or *alæ*, and the superior the *standard* or *vexillum.* Sometimes all the petals are coherent into a tube [as in *Trifolium*]. The filaments of the ten stamens are either coherent into a tube (*monadelphous*) surrounding the pistil, or nine of them form a tube open above, the tenth lying in front of the cleft (*diadelphous*). The ovary is superior, bearing the ovules on its ventral suture ; usually unilocular, but sometimes, as in *Astragalus* (Fig. 288, p. 142), almost bilocular from the folding in of the margin of the carpel. The fruit is a unilocular capsule (*legume*), splitting into two valves by both dorsal and ventral suture; but sometimes nearly bilocular, like the ovary, or multilocular by the formation of masses of cellular tissue between the seeds ; and then it sometimes breaks up into sections by the contraction of the pericarp between the seeds, when it is termed a *lomentum* (Fig. 516, II.); rarely indehiscent, as in the sainfoin. The seeds are usually exalbuminous, rarely with a small endosperm ; the embryo curved, with the radicle lying on the cleft of the cotyledons. [Among the more important genera are *Baptisia*, *Crotalaria*, *Lupinus*, *Genista*, *Ulex*, *Cytisus*, *Ononis*, *Trigonella*, *Medicago*, *Melilotus*, *Trifolium*, *Anthyllis*, *Lotus*, *Psoralea*, *Indigofera*, *Wistaria*, *Robinia*, *Colutea*, *Astragalus*, *Oxytropis*, *Glycyrrhiza*, *Ornithopus*, *Coronilla*, *Hippocrepis*, *Hedysarum*, *Onobrychis*, *Adesmia*, *Arachis*, *Desmodium*, *Cicer*, *Vicia*,

Lens, *Lathyrus*, *Pisum*, *Kennedya*, *Butea*, *Phaseolus*, *Dolichos*, *Dalbergia*, *Pterocarpus*, *Sophora*, *Myroxylon*, *Swartzia*.] The most valuable agricultural and culinary plants are the scarlet-runner and French bean, *Phaseolus multiflorus* and *vulgaris*; the field and garden-pea, *Pisum sativum*; the vetch, *Vicia sativa*; the bean, *Vicia Faba*; the lentil, *Ervum Lens*; the chick-pea, *Cicer arietinum*; the lucerne, *Medicago sativa*; the sainfoin, *Onobrychis sativa*; the white lupin, *Lupinus albus*; and the clovers, *Trifolium pratense*, *repens*, and *incarnatum*. Among officinal products are the root of the rest-harrow, *Ononis spinosa*, and

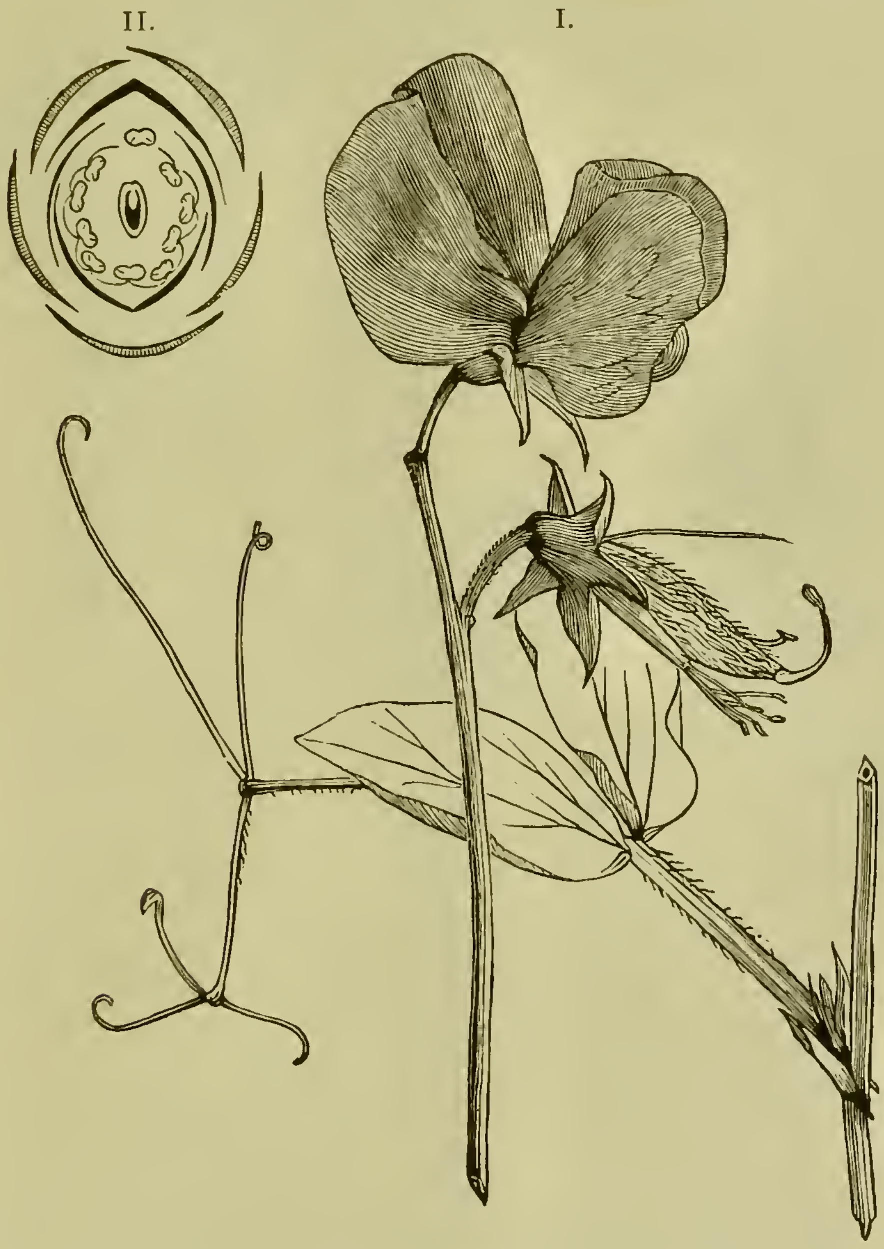


FIG. 514.—Sweet-pea, *Lathyrus odoratus*; I. natural size; II. floral diagram.

the foliage and inflorescence of the melilot, *Melilotus officinalis.* Liquorice is obtained from the roots of *Glycyrrhiza echinata* and *glabra* from southern Europe ; several species of *Myroxylon* of Peru and Colombia yield balsam of Peru ; the boiled sap of the bark of *Drepanocarpus senegalensis* is known as 'kino africanum ;' gum-tragacanth is obtained from several species of *Astragalus* from Asia Minor ; and indigo from the East Indian *Indigofera tinctoria* ; sandal-wood is the timber of *Pterocarpus santalinus* from the East Indies. [The seeds of *Arachis hypogæa* (earth-nuts) are eaten in the West Indies ; *Colutea arborescens* is the bladder-senna.]

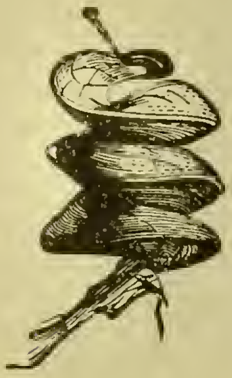


FIG. 515. — Twisted legume of lucerne, *Medicago sativa* (magnified).

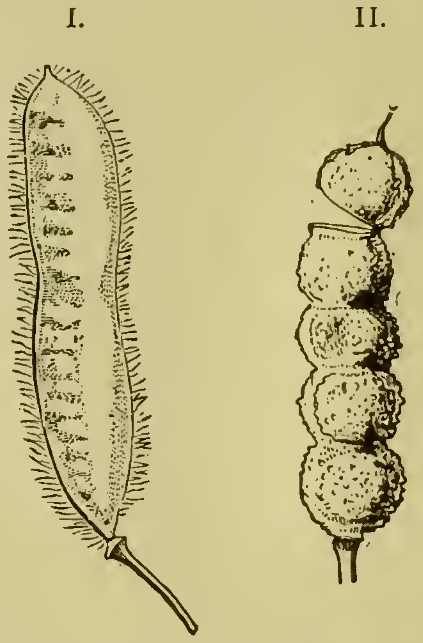


FIG. 516.—I. Legume of *Genista* ; II. lomentum of *Hedysarum* (natural size).

2. *Cæsalpinieæ.* This suborder is distinguished from the Papilionaceæ by the almost regular not papilionaceous corolla, which is, however, sometimes absent, by the straight embryo, and by the ten or fewer stamens being all free (not coherent). They are always trees or shrubs. [Important genera :—*Cæsalpinia*, *Hæmatoxylon*, *Gleditschia*, *Cassia*, *Ceratonia*, *Bauhinia*, *Cercis*, *Amherstia*, *Tamarindus*, *Hymenæa*, *Copaifera*.] This suborder is entirely extra-European, but yields a considerable number of officinal or economical products. Tamarinds are the fruit of the East Indian *Tamarindus indica* ; the leaves of *Cassia lanceolata* and *elongata* are senna ; balsam of copaiba comes from several species of *Copaifera*, natives of the West Indies and Guiana ; *Ceratonia Siliqua* of the eastern Mediterranean is the carob ; and *Dipteryx odorata* of Guiana the poisonous tonka-bean. *Cæsalpinia echinata* and *brasiliensis* of Brazil yield Brazil-wood, containing a

red colouring principle ; *C. Sappan* is the red sappan-wood of Eastern India, and *Hæmatoxylon campechianum* of Central America, logwood.

3. *Mimoseæ* (Fig. 517). This suborder is also extra-European and chiefly Australian and East Indian. They are distinguished from the Papilionaceæ by the valvate æstivation of the calyx, and the regular, often gamopetalous, corolla. The stamens are sometimes very numerous, and either coherent or free. [The leaves are often replaced by phyllodes,) see p. 91). Principal genera :—*Mimosa*, *Acacia*. The suborder includes the sensitive plants *Mimosa pudica* and *sensitiva*

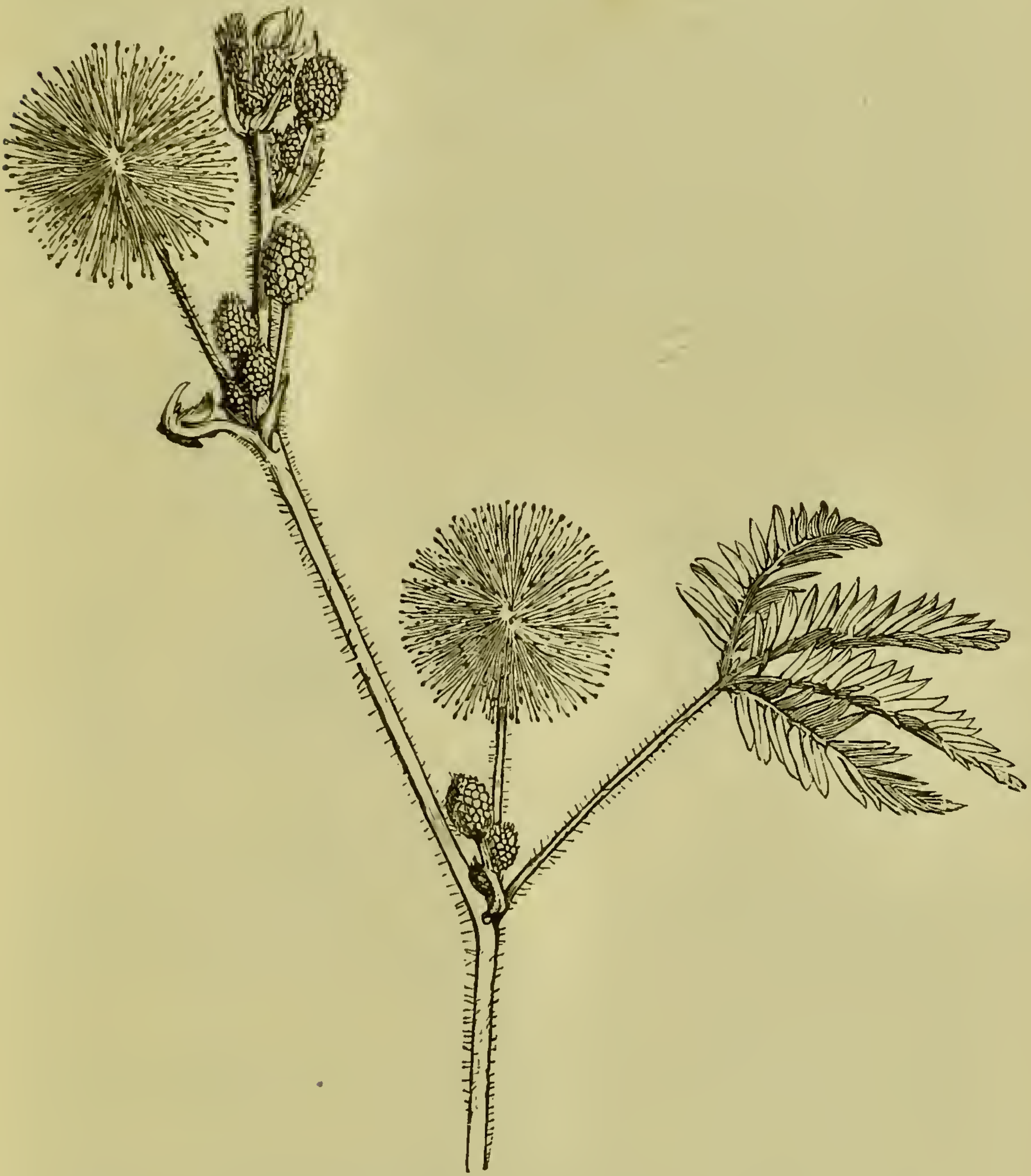


FIG. 517.—Sensitive-plant, *Mimosa pudica* (natural size) (see p. 202).

(see p. 202), and the true *Acacias.*] Gum arabic is obtained from *Acacia Seyal*, *tortilis*, and *Ehrenbergiana*, all natives of tropical Africa; 'terra japonica,' or catechu, is the sap of *Acacia Catechu* of Bengal and Coromandel.

Order 2. ROSACEÆ. The leaves are stipulate; the calyx regular and usually gamosepalous and 5-partite, the odd section superior; the corolla regular; the petals distinct, attached to the margin of the calyx, and equal in number with its teeth; the stamens perigynous, usually many times the number of the petals, and bent inwards in vernation; the ovary sometimes monocarpellary, but more often multicarpellary, the carpels being either free or coherent with one another and with the calyx; the fruit dry or succulent, a berry, drupe, or a number of achenes or follicles; the seeds exalbuminous. This large and important order is again divided into suborders:—

1. *Pomeæ.* (Figs. 518, 519). Trees or shrubs with alternate usually simple leaves furnished with free deciduous stipules. The flowers are regular and arranged in short terminal umbels, racemes, or cymes, often corymbose; the calyx-limb is 5-cleft or 5-toothed, imbricate in æstivation, and remaining dry and persistent on the fruit; the stamens numerous, and, like the five petals, attached in a ring to the base of the calyx (Fig. 518); the ovary is as a rule 5-, more rarely 2- or 3-locular, each loculus usually containing two ovules; styles equal in number to the loculi. The fruit [or pseudocarp (see p. 147)] is succulent, a berry or pome, or formed of a number of drupes, the pericarp being thin, cartilaginous, or stony. [Principal genera:—*Pyrus*, *Cotoneaster*, *Cratægus*, *Malus*, *Sorbus*, *Mespilus*, *Cydonia.*] Among edible fruits are the apple and pear *Pyrus Malus* and *communis*, the quince *Cydonia vulgaris*, the

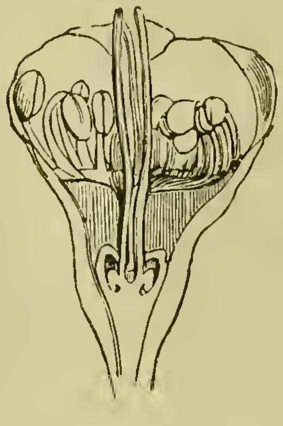


FIG. 518.—Longitudinal section through the flower of the pear (magnified).

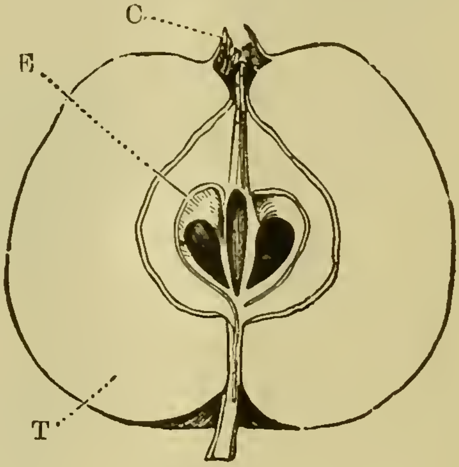


FIG. 519.—Longitudinal section through an apple; C dry persistent calyx-limb; E loculi with cartilaginous pericarp; T mesocarp (reduced).

medlar *Mespilus germanica*, the hawthorn or whitethorn *Cratægus oxyacantha*, and the mountain ash *Sorbus aucuparia*.

2. *Roseæ* (including Sanguisorbeæ, Dryadeæ, and Spiræeæ) (Figs. 520–522). Herbs, shrubs, or trees, usually with pinnate or digitate leaves, provided with stipules adherent to the base of the petiole. In the number and structure of the parts of the flower Roseæ agree for the most part with Pomeæ, but are best distinguished by the numerous free and unilocular ovaries, not adherent to the calyx. The 5-, rarely 4-cleft gamosepalous calyx has a tube of various structure, and is often surrounded by a 4- or 5-cleft epi-calyx or involucre, the leaves of which alternate with the sepals; the petals are perigynous [sometimes wanting]; the stamens rarely so few as five, usually 12 to 100, free and also perigynous; the ovaries mostly with only a single anatropous ovule; and the style usually more or less lateral. [Principal genera :—*Rosa*, *Alchemilla*, *Poterium*, *Sanguisorba*, *Agrimonia*, *Rubus*, *Fragaria*, *Geum*, *Comarum*, *Dryas*, *Potentilla*, *Spiræa*.] The fleshy calyx-tube or receptacle of the rose forms an edible pseudocarp known as a hip; true edible fruits are borne by the raspberry *Rubus Idæus*, and blackberry *R. fruticosus*; an edible receptacle or pseudocarp (see p. 146) by the strawberry *Fragaria vesca*, *elatior*, and *grandifolia*. Oil of roses is obtained from *Rosa moschata* and *damascena* of Asia Minor. The bark of *Quillaja saponaria* of Chile is saponaceous, and known as soap-wood; the flowers of *Margera anthelmintica*

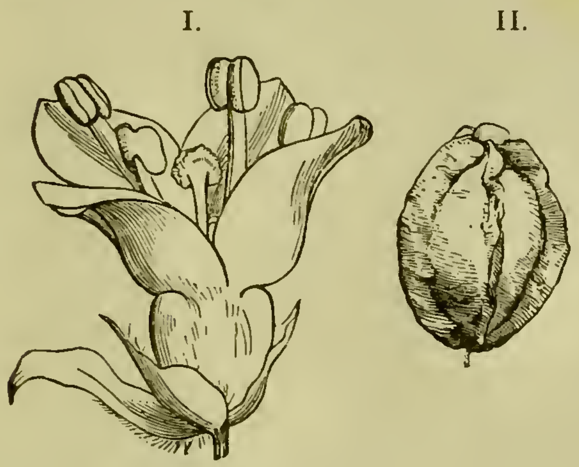


Fig. 520.—*Sanguisorba officinalis*; I. flower; II. fruit (magnified).

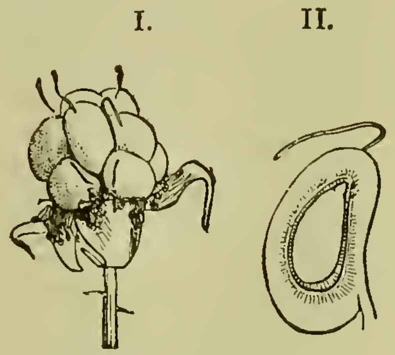


Fig. 521.—Fruit of dewberry (*Rubus cæsius*); I. natural size; II. a single drupel (magnified).

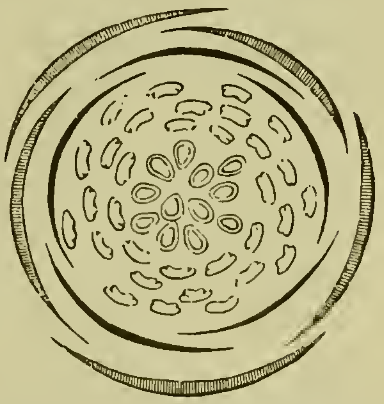


Fig. 522.—Floral diagram of the rose. See Fig. 256, p. 133.

of Abyssinia are a powerful anthelmintic; the root of *Geum urbanum* and of *Tormentilla recta* are also officinal.

3. *Amygdaleæ* (or Drupaceæ). Shrubs or trees with simple alternate leaves provided with free deciduous stipules. This suborder is distinguished from the rest of the order by the ovary, which is composed of a single superior carpel not adherent to the calyx, and which developes into a drupe (see p. 152). In the course of development the pericarp becomes differentiated into three layers, of which the outermost or *epicarp* forms a more or less tough skin, the middle layer, the *mesocarp* or *sarcocarp*, a more or less pulpy flesh, and the inner one, the *endocarp* or *putamen*, a hard stone. The fruit contains one or rarely two seeds with fleshy cotyledons, and radicle directed upwards (see Figs. 220 and 325 I. pp. 119, 153). [Principal genera:—*Amygdalus*, *Cerasus*, *Persica*, *Prunus*, *Armeniaca*.] This suborder is marked by the tendency to form substances containing hydrocyanic acid, which is found especially in the seeds of the peach, apricot, cherry, plum, sloe *Prunus spinosa*, bitter almond, and in the leaves of the cherry-laurel *Prunus lauro-cerasus*. Edible fruits or seeds are furnished by the almond *Amygdalus communis*, peach *Persica vulgaris*, nectarine *P. lævis*, cherry, species of *Cerasus*, apricot *Armeniaca vulgaris*, and plum *Prunus domestica*. [The stem of many species yields gum, and the wood a valuable timber for cabinet-work.

Besides other less important orders belonging to this large cohort, are *Saxifragaceæ* (*Saxifraga*, *Chrysosplenium*, *Hoteia*, *Astilbe*, *Cunonia*, *Hydrangea*, *Escallonia*, *Deutzia*, *Ribes*, *Cephalotus*, *Philadelphus*, *Parnassia*); *Crassulaceæ* (*Tillæa*, *Cotyledon*, *Crassula*, *Sedum*, *Sempervivum*, *Bryophyllum*, *Echeveria*, *Umbilicus*); *Droseraceæ* (*Drosera*, *Dionæa*; see pp. 169, 203).

DIVISION IV. DISCIFLORÆ.—*Sepals distinct or united, free or adnate to the ovary; petals distinct; disc usually conspicuous as a ring or cushion, or spread over the base of the calyx-tube, or confluent with the base of the ovary, or broken up into glands; stamens usually definite, inserted upon or at the outer or inner base of the disc; ovary superior.*

Cohort I. SAPINDALES. Flowers often irregular and unisexual; disc tumid, adnate to the base of the calyx or lining its tube; stamens perigynous or inserted upon the disc, or between it and the ovary, usually definite; ovary entire, lobed, or apocarpous; ovules one to two in each loculus, usually ascending with a ventral raphe, or reversed, or pendulous, from a basal funiculus, rarely indefinite and horizontal; seed usually exalbuminous; embryo often curved or crumpled. Shrubs or trees, mostly with compound leaves. Principal orders :—*Sapindaceæ* (*Paullinia*, *Æsculus*, *Sapindus*, *Pavia*, *Acer*, *Negundo*, *Dodonæa*, *Staphylea*) ; *Terebinthaceæ* (*Rhus*, *Pistacia*, *Mangifera*, *Anacardium*).

Cohort II. CELASTRALES. Flowers hermaphrodite, regular ; corolla hypogynous or perigynous ; disc tumid, adnate to the base of the calyx-tube or lining it ; stamens as many as the petals or fewer, rarely twice as many, perigynous or inserted outside the disc or on its edge ; ovary usually entire ; ovules one to two in each loculus, erect ; raphe ventral. Shrubs or trees, rarely herbs, usually with undivided leaves. Principal orders :—*Celastraceæ* (*Euonymus*, *Elæodendron*, *Celastrus*, *Hippocratia*) ; *Rhamnaceæ* (*Paliurus*, *Zizyphus*, *Rhamnus*, *Ceanothus*) ; *Ampelideæ* (*Cissus*, *Vitis*, *Ampelopsis*).

Cohort III. GERANIALES. Flowers often irregular ; disc usually annular, adnate to the stamens or reduced to glands, rarely absent ; ovary multicarpellary, syncarpous or subapocarpous; ovules one to two, rarely numerous in each carpel, ascending or pendulous ; raphe usually ventral. To this very large cohort belong the following orders, in addition to others of less importance:—*Linaceæ* (*Linum*, *Erythroxylon*); *Malpighiaceæ* (*Malphigia*); *Zygophyllaceæ* (*Tribulus*, *Zygophyllum*, *Fagonia*, *Guaiacum*); *Geraniaceæ* (*Geranium*, *Erodium*, *Pelargonium*, *Tropæolum*, *Limnanthes*, *Oxalis*, *Biophytum*, *Averrhoa*, *Impatiens*) ; *Rutaceæ* (*Ruta*, *Dictamnus*, *Peganum*, *Diosma*, *Barosma*, *Eriostemon*, *Correa*, *Zanthoxylum*, *Citrus*, *Ægle*, *Limonia*); *Simarubaceæ* (*Quassia*, *Samadera*, *Simaba*, *Cneorum*, *Simaruba*, *Brucea*, *Ailantus*, *Balanites*, *Picramnia*) ; *Burseraceæ* (*Boswellia*, *Canarium*, *Balsamodendron*, *Bursera*, *Amyris*) ; *Meliaceæ* (*Melia*, *Swietenia*, *Cedrela*, *Chloroxylon*).

DIVISION V. THALAMIFLORÆ.—*Sepals usually distinct and separate, free from the calyx ; petals in one, two, or many whorls, hypogynous ; stamens hypogynous, rarely inserted on a longer or shorter receptacle or on a disc ; ovary superior.*

Cohort I. MALVALES. Flowers usually regular ; sepals five, rarely two to four, free or united, valvate or imbricate ; petals as many as sepals, or absent ; stamens usually indefinite and monadelphous ; ovary 3-locular or more, rarely monocarpellary ; placentation axile. Shrubs, rarely herbs or trees, with alternate, usually stipulate, simple or compound leaves.]

Order 1. MALVACEÆ. (Fig. 523.) Herbs, shrubs, or trees, with simple, alternate, stipulate leaves. The calyx is 3- to 5-cleft, and usually surrounded by an epi-calyx or involucre of bracts ; the petals are equal in

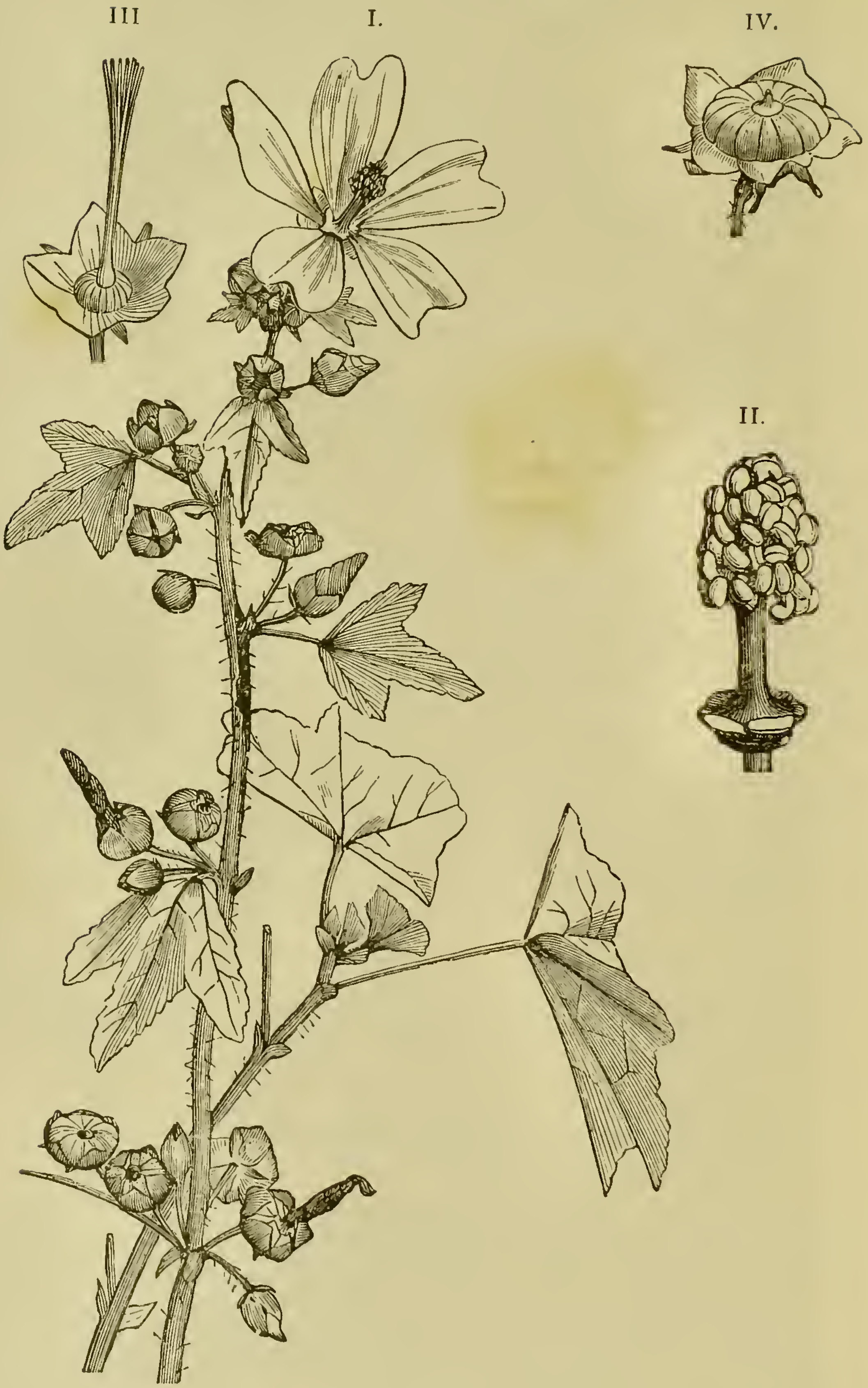


FIG. 523.—*Malva sylvestris*; I. portion of plant (reduced); II. the monadelphous stamens (magnified); III. the pistil; IV. the fruit (natural size).

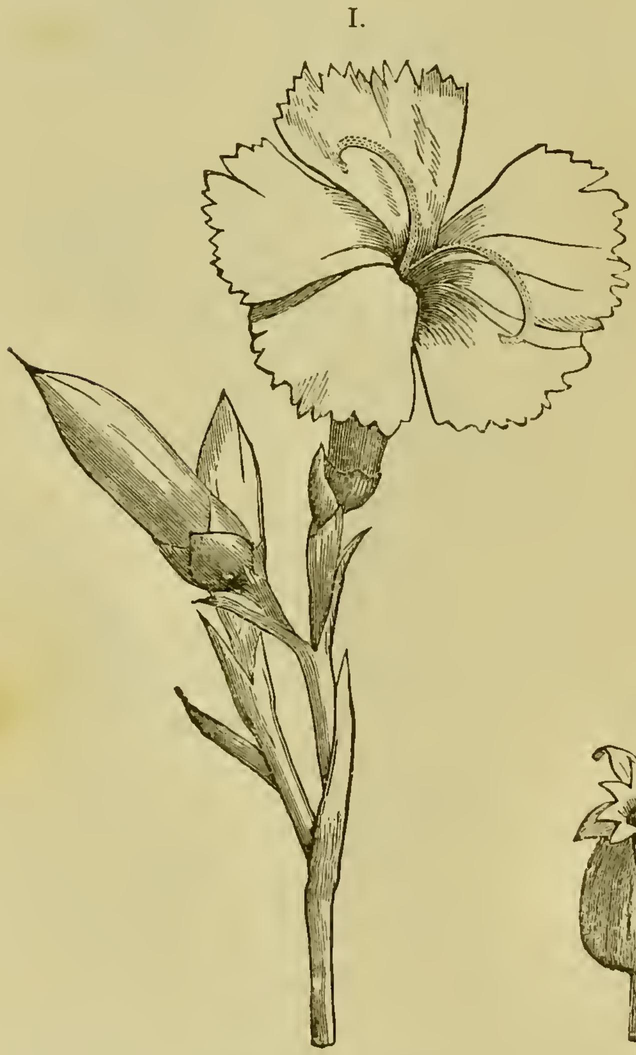
number to the lobes of the calyx, and contorted in æstivation [while the calyx is valvate]; the filaments of the numerous stamens are coherent at their base with the petals, and united into a tube which encloses the superior ovary; the anthers are unilocular and dehisce in a semicircular line; the ovary multicarpellary, the carpels arranged round a central axis, and either free or united; the fruit a capsule or schizocarp; the cotyledons of the straight embryo are folded together, and the seed has little or no endosperm. [Principal genera:—*Malope*, *Althæa*, *Lavatera*, *Malva*, *Hibiscus*, *Gossypium*, *Sida*, *Abutilon*, *Adansonia*, *Bombax*, *Eriodendron*, *Durio*.] Many plants belonging to this order are officinal on account of the quantity of mucilage they contain, as the roots of *Althæa officinalis*, the flowers of the hollyhock *Althæa rosea*, and of *A. sylvestris*, and the foliage of *Malva rotundifolia*. Cotton consists of the hairs attached to the testa of several species of *Gossypium*, especially *G. herbaceum*, *arboreum*, and *religiosum*, natives of all tropical countries. The baobab, *Adansonia digitata* of West Africa, is one of the most gigantic of trees. [The fruit of *Durio* is edible.

The other orders of the cohort are *Sterculiaceæ* (*Lasiopetalum*, *Buttneria*, *Theobroma*, *Sterculia*, *Thomasia*); and *Tiliaceæ* (*Grewia*, *Tilia*, *Triumfetta*, *Corchorus*, *Elæocarpus*).

Cohort II. GUTTIFERALES. Flowers regular; sepals and petals each usually four or five, imbricate in bud; stamens usually indefinite; ovary 3- to multi-locular, rarely 1- or 2-locular; placentation axile. Trees or shrubs, rarely herbs. Principal orders:—*Hypericaceæ* (*Hypericum*); *Guttiferæ* (*Clusia*, *Garcinia*); *Camelliaceæ* (*Ternstrœmia*, *Camellia*, *Thea*, *Caraipa*, *Marcgravia*); *Dipterocarpaceæ* (*Dryobalanops*, *Dipterocarpus*, *Shorea*, *Vateria*).

Cohort III. CARYOPHYLLALES. Flowers regular; sepals two to five, rarely six; petals usually as many as sepals; stamens as many or twice as many, rarely more or fewer; ovary unilocular, or imperfectly 2- to 5-locular; placentation free central, rarely parietal; ovules campylotropous; embryo usually curved, in a floury endosperm.]

Order 1. CARYOPHYLLACEÆ. (Figs. 524, 525.) Herbs, very rarely shrubs, with simple, entire, opposite leaves, springing from tumid nodes, and cymose inflorescence. The flowers are regular and pentamerous; the calyx 5-cleft or 5-toothed, sometimes of 5 distinct sepals; the corolla of 5 distinct petals, which are often deeply bifid; the stamens 10, in two rows, though all are not always perfectly developed, the five inner ones often coherent with the base of the petals; the pistil consists of from two to five carpels; the placentation is free central, from the original dissepiments breaking away from the outer wall of the ovary before maturity; the styles are free and equal in number to the original divisions of the ovary; the fruit a capsule dehiscing with teeth. The seeds have a floury endosperm, and a long curved embryo, which either entirely surrounds the endosperm or lies on one side of it. Some species are monœcious, diœcious, or polygamous, from the abortion of pistil or stamens. [Principal genera :—*Agrostemma*, *Silene*, *Lychnis*, *Cucubalus*, *Viscaria*, *Saponaria*, *Gypsophila*, *Dianthus*, *Cerastium*, *Stellaria*, *Arenaria*, *Alsine*, *Spergula*.] With the exception that some species are



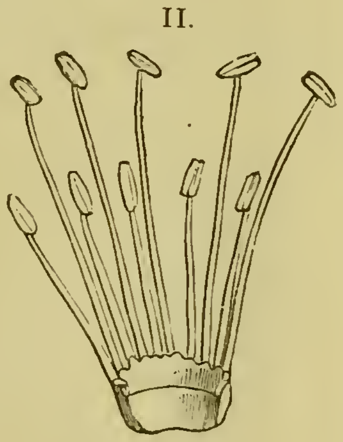


FIG. 524.—*Dianthus Caryophyllus*: I. portion of plant (natural size); II. stamens (magnified). See Figs. 250, 251, p. 131; 254, 255, p. 132.

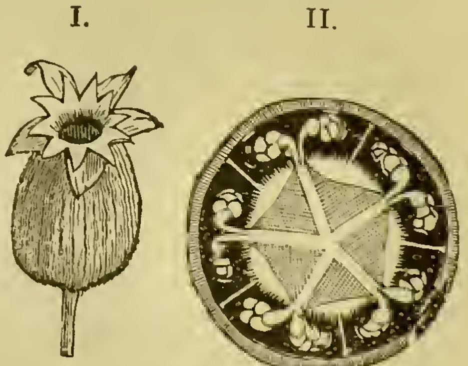


FIG. 525.—White campion, *Lychnis vespertina*; I. fruit (natural size); II. transverse section through ovary. See Fig. 254, p. 132.

saponaceous, the order is entirely destitute of economic properties; but many are grown in gardens for the beauty of their flowers.

[The only other order of importance belonging to the cohort is *Portulacaceæ* (*Claytonia*, *Portulaca*, *Sesuvium*, *Mollugo*).

Cohort IV. POLYGALALES. Flowers regular or irregular; sepals and petals five each, rarely four or three ; stamens as many or twice as many as petals ; ovary 2-locular, rarely unilocular or more ; endosperm fleshy, rarely absent. Herbs, shrubs, or trees, with exstipulate leaves. Principal order *Polygalaceæ* (*Polygala*, *Krameria*, *Securidaca*).

Cohort V. PARIETALES. Stamens definite or indefinite ; carpels connate into a unilocular ovary with parietal placentation, rarely spuriously bilocular or more by the prolongation of the placentæ (carpels occasionally free ; ovary occasionally 3-locular or more).]

Order I. PAPAVERACEÆ. (Fig. 526.) Herbs with a yellow or white latex. The sepals are two, distinct, deciduous ; the petals four, arranged in two whorls, regular [and deciduous] ; the stamens indefinite, free and hypogynous ; the ovary unilocular or spuriously multilocular ; the seeds with a small straight embryo at the base of a copious endosperm ; the fruit a capsule, either bursting into two valves, and resembling a siliqua (Fig. 526, II.), or opening by pores, four to twenty in number, situated beneath the peltate stigma (see Figs. 233, 294, 313, pp. 126, 144, 150). [Principal genera :—*Platystemon*, *Chelidonium*, *Sanguinaria*, *Papaver*, *Eschscholtzia*, *Argemone*, *Glaucium*, *Meconopsis*, *Ræmeria*.] Among officinal products of the order are the foliage of the larger celandine *Chelidonium majus*, the petals of the common poppy *Papaver Rhœas*, and the dried latex of the unripe capsules of the opium-poppy *Papaver somniferum*. The latter is an important article of commerce from Egypt, Turkey, [India, and China], yielding opium and laudanum.

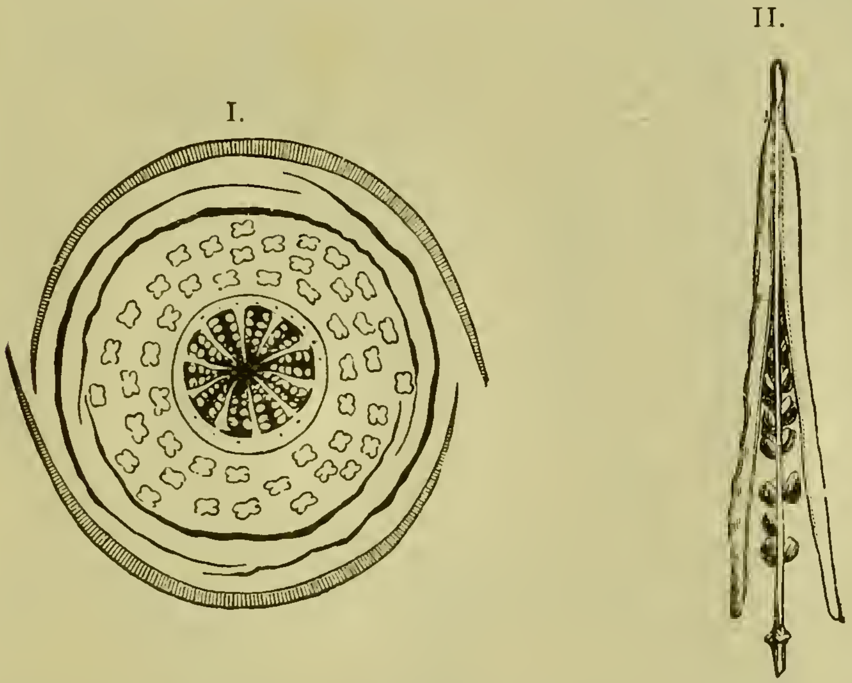


FIG. 526.—I. Floral diagram of *Papaver* ; II. capsule (siliqua) of *Chelidonium* (natural size).

Order 2. CRUCIFERÆ. (Figs. 527–530.) Herbs with alternate exstipulate leaves. The sepals are four, usually deciduous; the petals four,

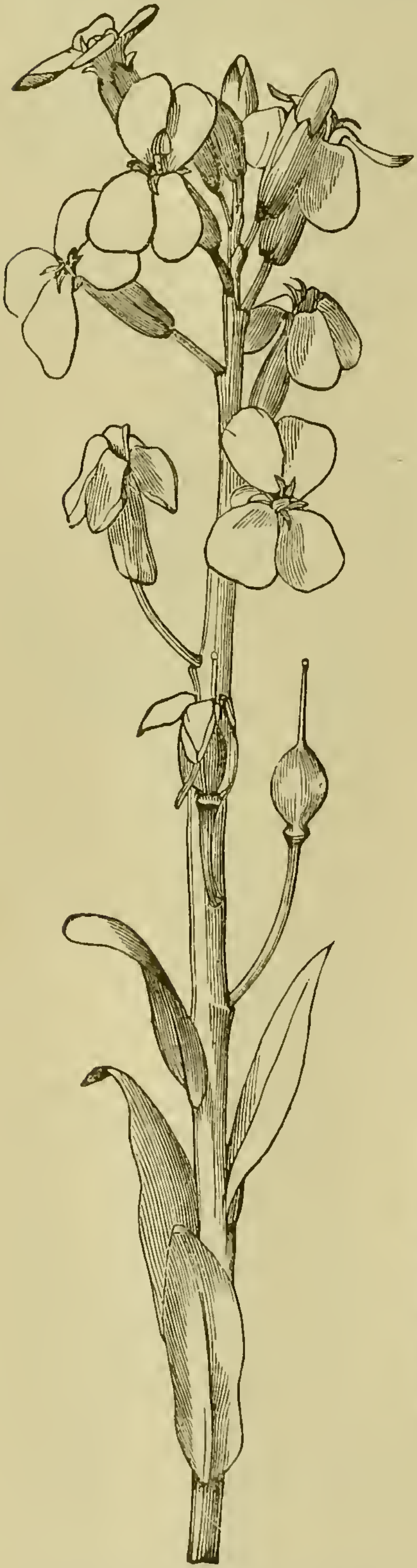


FIG. 527 — *Vesicaria utriculata* (Siliculosæ, natural size).

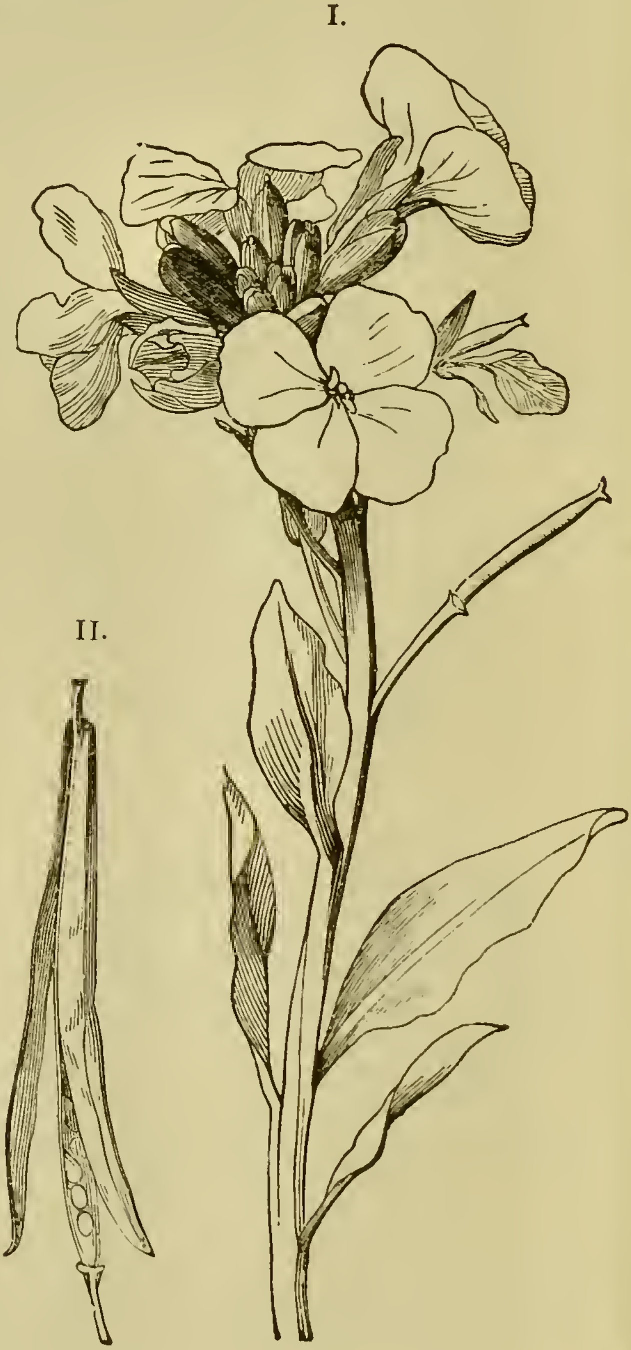


FIG. 528. — Wallflower, *Cheiranthus Cheiri* (Siliquosæ); I. part of plant; II. siliqua (natural size).

alternate with them, arranged in a cross, and usually unguiculate ; the stamens six, *tetradynamous*, the two shorter ones belonging to an outer whorl and opposite to the carpels, the four longer ones to an inner whorl and attached in front of the placentæ (see Figs. 200, 204, pp. 111, 112). The ovary is superior ; the fruit as a rule a bilocular capsule, bursting from the base upwards ; if it is several times longer than broad, it is termed a *siliqua* (Fig. 528, II.); if only slightly or not at all longer than broad a *silicula* (Fig. 527). According as the dissepiment or *replum*, when seen in transverse sections, occupies the shorter or longer diameter, the silicula is said to be *angustisept*, as in the shepherd's purse, *Capsella* (Fig. 530, II.), or *latisept* as in *Camelina* (Fig. 530, III.). Less often the siliqua splits transversely, forming a *lomentum*, as in the radish, *Raphanus* (Fig. 530, IV.), or the fruit is a schizocarp, often at first bilocular, but ultimately unilocular by the disappearance or perforation of the dissepiment, as in the dyer's woad *Isatis* (Fig. 530, I.). The seeds are exalbuminous, with a curved embryo, the position of which is an important character in the classification of the genera belonging to the order (see p. 157). [This large and important order is divided into several suborders, and includes a large number of genera, of which the following are the more important :—*Matthiola*, *Cheiranthus*, *Nasturtium*, *Barbarea*, *Arabis*, *Cardamine*, *Anastatica*, *Lunaria*, *Aubrietia*, *Vesicaria*, *Alyssum*, *Draba*, *Cochlearia*, *Schizopetalum*, *Hesperis*, *Malcolmia*, *Sisymbrium*, *Erysimum*, *Braya*, *Camelina*, *Brassica*, *Sinapis*, *Eru-*

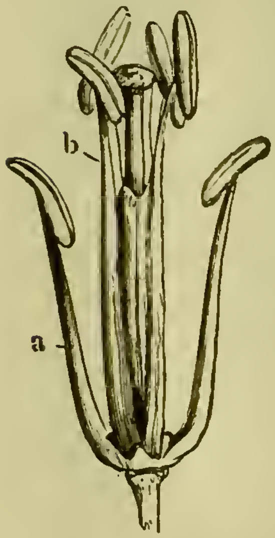


FIG. 529. — Tetradynamous stamens and pistil of *Brassica nigra* ; *a* shorter, *b* longer stamens.

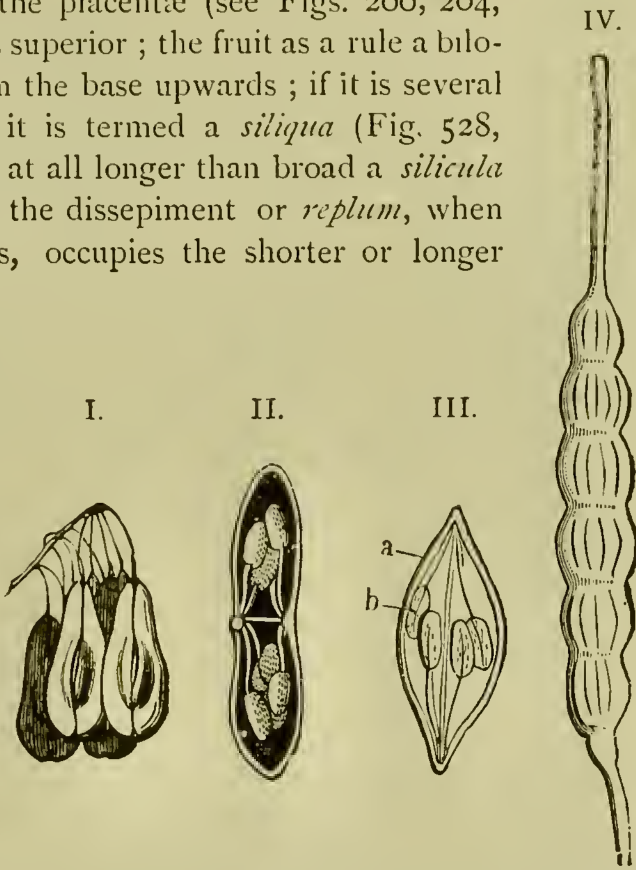


FIG. 530.—I. Schizocarps of *Isatis tinctoria* ; II. transverse section of angustisept silicula of *Capsella* ; III. transverse section of latisept silicula *a* of *Camelina* ; *b* four seeds ; IV. lomentum of *Raphanus*.

castrum, *Diplotaxis*, *Vella*, *Capsella*, *Senebiera*, *Lepidium*, *Megacarpæa*, *Thlaspi*, *Iberis*, *Teesdalia*, *Isatis*, *Myagrum*, *Bunias*, *Crambe*, *Cakile*, *Erucaria*, *Raphanus*, *Dentaria*, *Alliaria*, *Armoracia*, *Pringlea*.] It furnishes a large number of culinary vegetables. The common cabbage, *Brassica oleracea*, is the parent-form of all the varieties, as kohl-rabi, savoy, Brussels sprouts, broccoli, cauliflower, &c. [the two latter forms owing their peculiarity to a suppression of the floral organs, and an abnormal development of the pedicels of the inflorescence]. The seeds of other species contain an oil known as rape-seed oil. The turnip and Swede are varieties of *Brassica Napus*. Other culinary species are the water-cress *Nasturtium officinale*, and the garden-cress *Lepidium sativum*. The rhizome of *Cochlearia Armoracia* is known as horse-radish ; the root of *Raphanus sativus* is the common radish ; mustard is obtained from the seeds of *Sinapis nigra*. [The antiscorbutic properties possessed by so many plants belonging to this order are due to the presence of a principle containing sulphur.] A large number of species are grown for the beauty of the flowers, among others the so-called 'rose of Jericho,' *Anastatica hierochuntica*. [The leaves of the woad, *Isatis tinctoria*, yield a blue dye.

[*Order* 3. VIOLACEÆ. Herbs with alternate, usually stipulate leaves ; corolla of 5 unequal petals, often spurred ; stamens 5, with adnate anthers and often prolonged connective. Fruit a unilocular 3-valved capsule with 3 parietal placentæ. Several species are purgative. Principal genera :—*Viola*, *Ionides*, *Alsodeia*.]

The remaining orders of importance belonging to the cohort are *Fumariaceæ* (*Hypecöum*, *Dicentra*, *Fumaria*, *Corydalis*) ; *Capparideæ*, (*Cleome*, *Capparis*) ; *Resedaceæ* (*Reseda*) ; *Cistaceæ* (*Cistus*, *Helianthemum*) ; *Bixaceæ* (*Bixa*, *Cochlospermum*, *Flacourtia*).

Cohort VI. RANALES. Stamens almost always indefinite ; carpels free or immersed in the receptacle, very rarely syncarpous ; micropyle usually inferior ; embryo minute in a fleshy endosperm.]

Order I. RANUNCULACEÆ (Figs. 531–533). Herbs with alternate, or less often shrubs [with opposite] leaves, exstipulate and often divided and semi-amplexicaul. The sepals are from three to six, [deciduous] and often petaloid ; the petals from 4 to 15, arranged in one or more rows, [some or all of them] often small and assuming the form of nectaries, (Fig. 533 III.) ; or the corolla is entirely absent ; the stamens free, indefinite, and hypogynous. The fruit consists of an indefinite number of one-seeded, indehiscent achenes, each representing a carpel with its own style and stigma [*Ranunculus*, *Anemone*], or of several follicles, *i.e.* capsules opening by the ventral suture only, [*Caltha*, *Pæonia*, *Delphinium*, *Aconitum*], or is more rarely a one- or several-seeded berry [Actæa]. The small embryo is enclosed in a copious fleshy endosperm. [Among the more important genera of this large order are *Clematis*, *Thalictrum*, *Anemone*, *Adonis*, *Myosurus*, *Ranunculus*, *Caltha*, *Hydrastis*, *Trollius*, *Helleborus*, *Eranthis*, *Nigella*, *Aquilegia*, *Delphinium*, *Aconitum*, *Actæa*, *Cimicifuga*, *Pæonia*.] Officinal products are the roots of the hellebore *Helleborus viridis*, the tubers of the

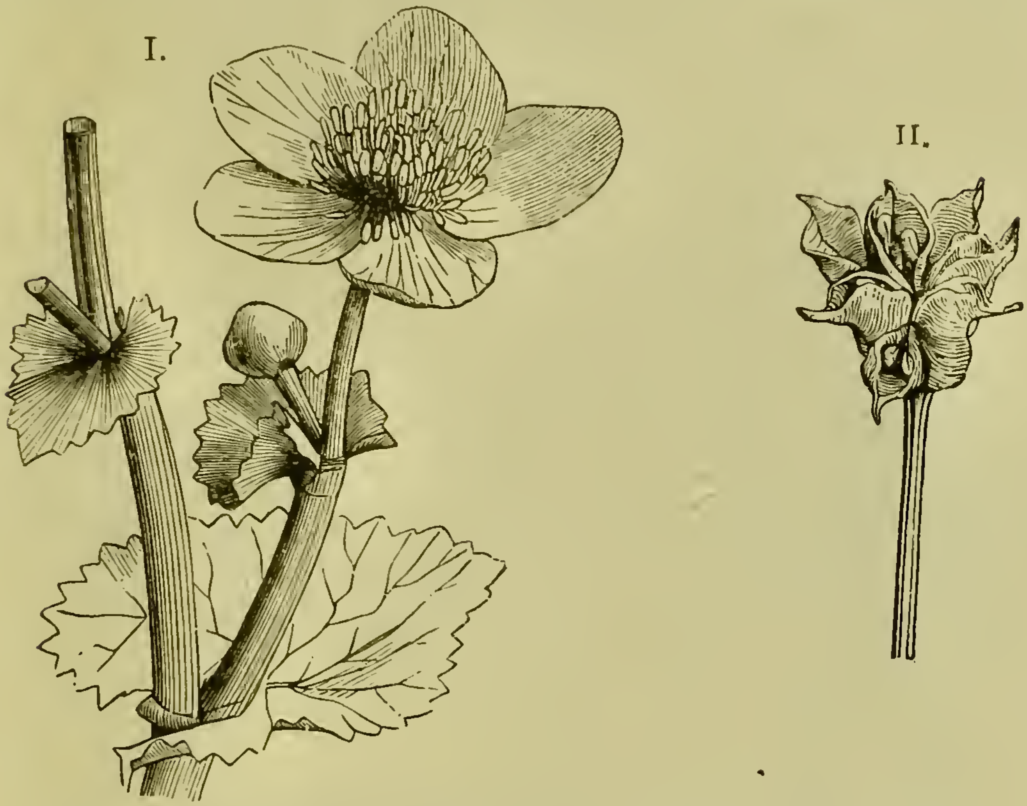


FIG. 531.—Marsh marigold, *Caltha palustris* ; I. part of plant ; II. fruit, consisting of follicles (natural size).

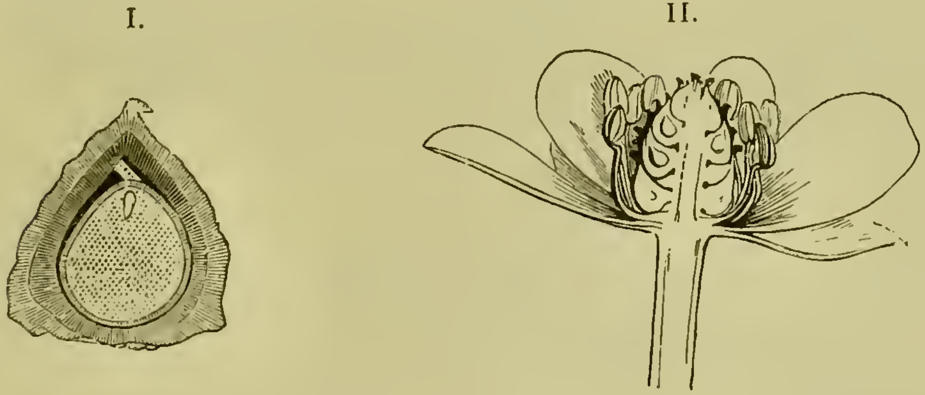


FIG. 532.—Pheasant's eye, *Adonis* : I. longitudinal section through achene ; II. longitudinal section through flower (magnified). (See also Fig. 209, p. 115.)

monkshood *Aconitum Napellus* (Fig. 533), the seeds of *Delphinium Staphisagria*, and the foliage of *Anemone Pulsatilla*. Many are poisonous, as the various species of *Helleborus* and *Aconitum*, and *Ranuculus sceleratus* ; and a large number are grown as ornamental plants.

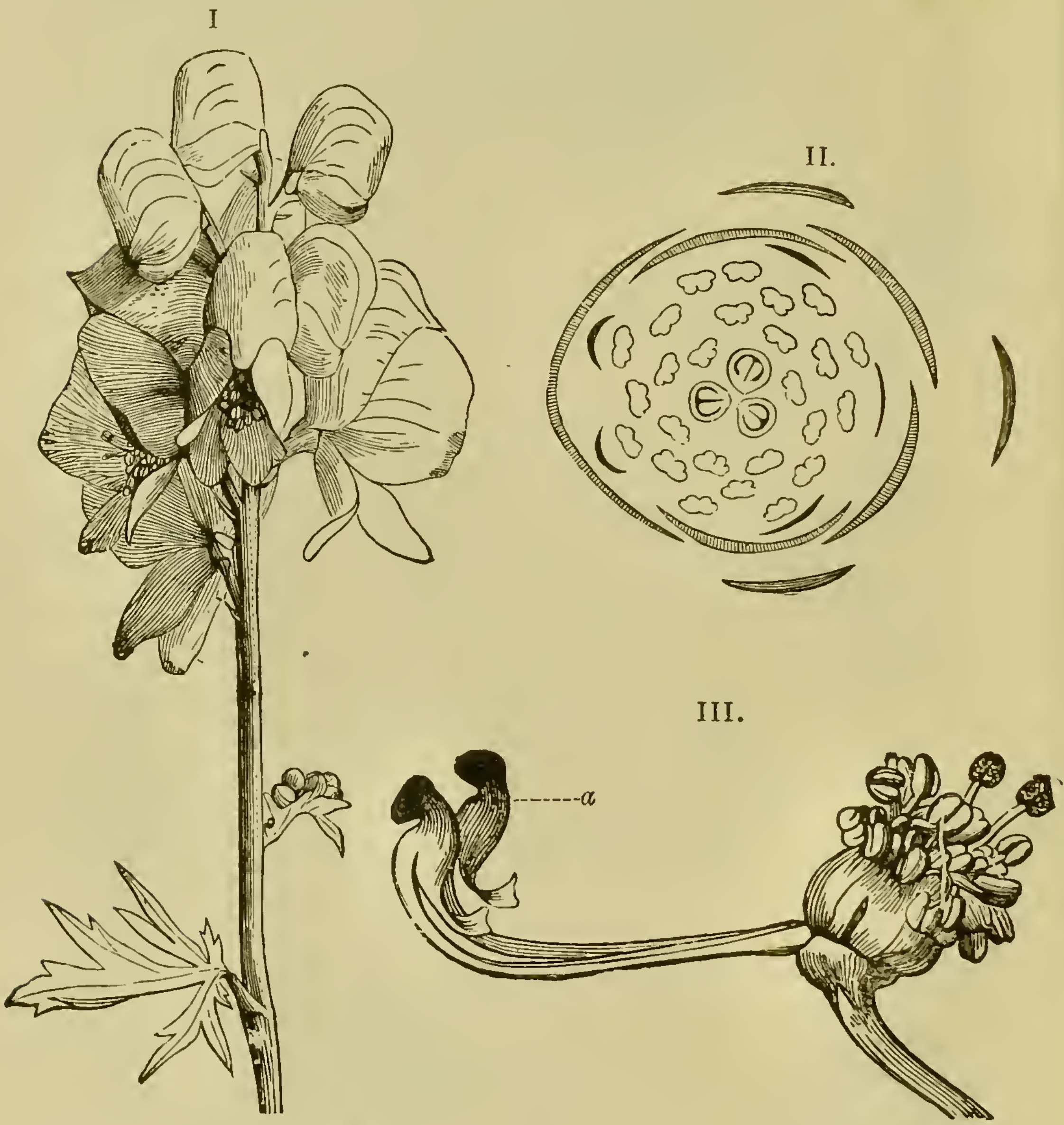


FIG. 533.—Monkshood, *Aconitum Napellus* ; I. part of plant (natural size) ; II. floral diagram ; III. flower (magnified), the coloured calyx having been removed, showing the two petals *a* developed into nectaries, the remaining petals being reduced to scales or altogether abortive.

[The remaining more important orders of the cohort are *Magnoliaceæ* (*Magnolia*, *Liriodendron*, *Drimys*, *Illicium*) ; *Anonaceæ* (*Uvaria*, *Anona*) ; *Menispermaceæ* (*Cissampelos*, *Cocculus*, *Anamirta*, *Menispermum*); *Berberideæ* (*Berberis*, *Mahonia*, *Epimedium*, *Podophyllum*); *Nymphæaceæ* (*Nuphar*, *Nymphæa*, *Victoria*, *Cabomba*, *Nelumbium*).]

CHAPTER VII.

THE CHANGES WHICH HAVE TAKEN PLACE IN THE VEGETATION OF THE GLOBE IN THE COURSE OF GEOLOGICAL PERIODS.

GEOLOGY, or the history of the formation of the earth, proves that the distribution of land and water on the surface of the globe has not always been the same as it is now; many districts which are now continents were at one time seas, and *vice versâ*. The main agent in carrying away masses of land from one spot and reconstructing them in another, has been water, either slowly by gradual action, or suddenly by mighty convulsions. Some idea may be conceived of the extent of this agency, from the reflection that the mass of particles in a state of suspension and solution which the river Ganges now carries down to the sea every year is equal in bulk to seventy pyramids as large as the largest of the Egyptian pyramids, that of Cheops. Wherever the substances that are carried down are deposited at the bottom of the sea or in sea-basins, strata are formed which at first fill up the unevennesses of the ground, the uppermost layers then forming gradually more and more horizontal deposits. On strata of this nature already in existence fresh layers of different substances are everywhere deposited. Such a *stratification* of the crust of the globe has not however occurred once only or a few times at one particular spot; but at almost every place where the surface has been excavated it manifests a structure stratified in the greatest variety of ways.

Nothing is more natural than that in these changes which have taken place on the surface of the earth, multitudes of plants[1] should have become enclosed in the soft deposits of mud, and their remains preserved in the rock which results from the hardening of the mud. The soft and delicate parts could not be perpetuated in this manner; and it is found in fact that only the harder parts, like the wood, bark, and fruits, are preserved (Fig. 534). The softer portions have been more or less quickly decomposed; although, under specially favourable conditions, there has been some preservation even of them. The delicate parts, for example, are

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[1] No account is taken in the sequel of the preservation of animal remains.

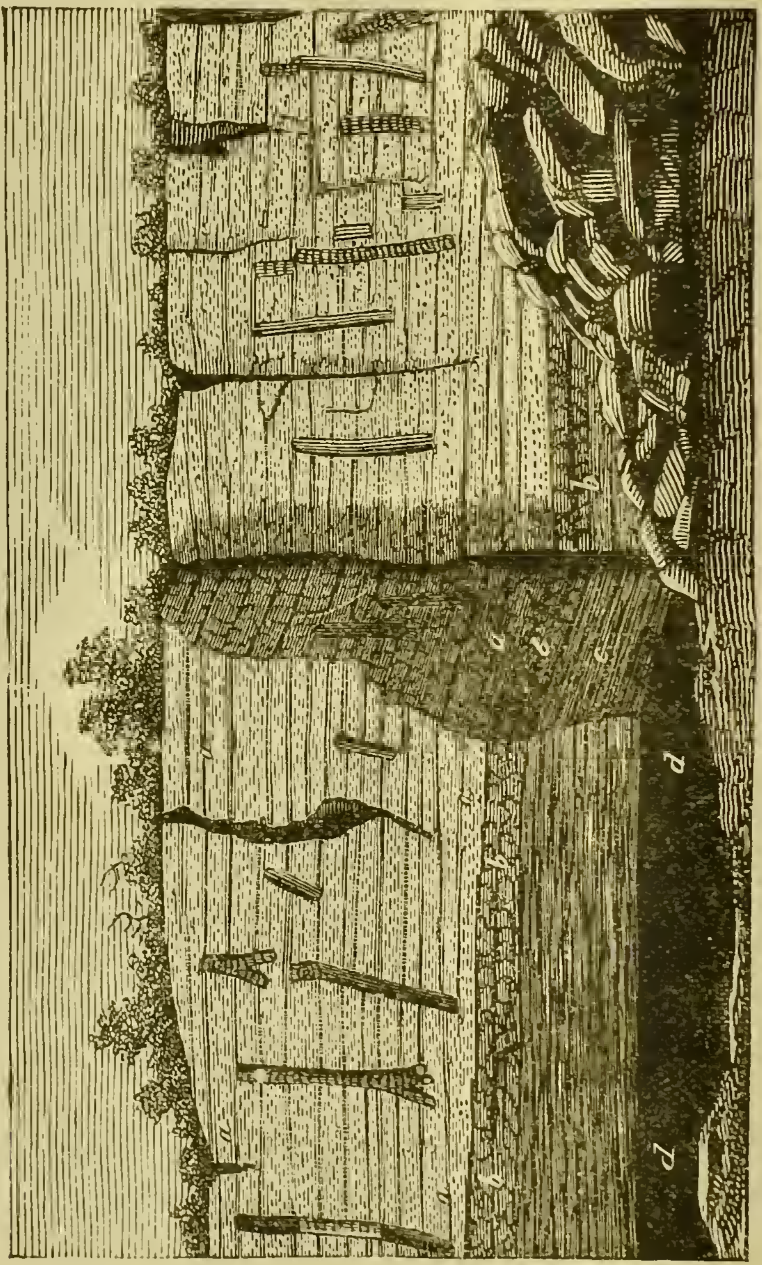

Fig. 534.—Section of coal-measures at St. Etienne; *a* bed of sandstone with erect stems of fossil trees; *b* bed of ironstone; *c* layer of shale; *d* bed of coal.

found enclosed in amber, and even in diamonds, or have been covered up by the hardening mud, and have at least left *impressions* in it, from which the form and even the species can be recognised. The numberless small cavities —cells and intercellular spaces—which are found in the substance of the plant are also not unfrequently filled with a fluid, the mineral constituents of which—usually silica—become gradually solid, and thus preserve the structure of the plant in a *fossil* form, the organic parts undergoing decomposition. From the mode in which these impressions and fossils are formed, it is evident that they can be found only in stratified rocks. The number and systematic position of the fossil remains obtained in this manner vary greatly in the different superincumbent strata; but are subject to the following general rules:—In the lowermost and consequently the oldest strata no remains of plants now living are found. In the higher strata are found gradually more and more highly organised kinds, and more nearly allied to those at present existing; this being most strikingly manifested in the uppermost or most recent beds, in which a number of fossil plants, or their impressions, are found, which belong to our existing flora. If, indeed, an attempt is made to form, from the few remains at present found, an idea of the entire vegetation—not, perhaps, of the whole earth, but of those regions which have furnished most material for examination—the result may not differ very widely from the reality. It is best to commence with the oldest strata, from which a gradual approach may be observed towards the existing vegetation of the earth.

In considering the variety of the fossil remains in the different strata, special attention must be paid to the changes which have taken place in the climate of the earth in the course of the different geological periods.[1]

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[1] [In his *Genera et Species Plantarum Fossilium*, published in 1850, Unger reckoned the number of genera and species of fossil plants known up to that time as under:—Exogens, 151 genera, 547 species; Endo-

In reference to the relative position of the strata, and to the fossil remains (chiefly those of animals) found in them, a number of *geological systems* are distinguished, which are again divided into *groups*.

The lowest strata of the *Primary* or *Palæozoic* age (*i.e.* the period of the oldest living beings)—*viz.* the strata of the *Silurian*[1] *system*—contain the earliest remains that have been preserved of the vegetable world. Only a few marine Algæ are known; but others may have altogether perished, their existence being indicated only by the occurrence of carbonaceous or bituminous limestone.

In the *Devonian system* the number of species, genera, and families has greatly increased. In addition to a considerable number of Algæ, the first land-plants have made their appearance. They consist almost entirely of the remains of Vascular Cryptogams, with a few Cycadeæ and Coniferæ. The aspect of this period, as also of that next in succession, must have been extraordinarily uniform and monotonous; but vegetable life had extended over the surface of the earth in a variety and luxuriance of forms far surpassing our existing vegetation.

In the *Carboniferous* period Ferns attained a special development. We find lofty trees or shrubs with multipinnate leaves several feet in length, forming magnificent groups of plants, in the shade of which other smaller species grew as underwood (Figs. 540–542). Among the largest forms of which these forests were composed were certain Lycopodiaceæ—to which nothing now existing is comparable—known as *Sigillariæ* and *Lepidodendra* (Figs. 535–539).

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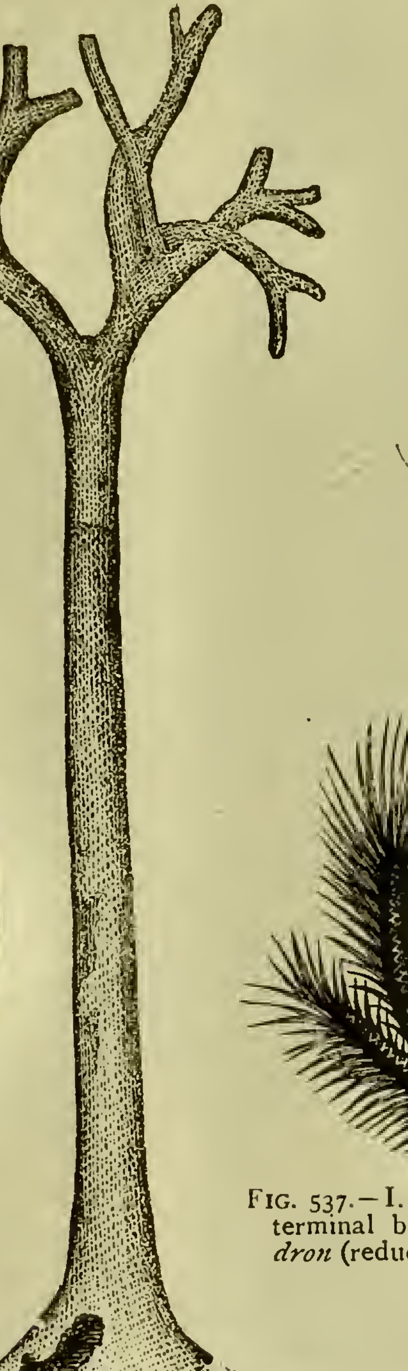
gens, 43 genera, 142 species; Gymnosperms, 56 genera, 363 species; Cryptogams, 152 genera, 1,172 species; Doubtful, 35 genera, 197 species. Since that time the number of both genera and species has been enormously increased, especially by the additions to the Tertiary flora made by Heer and Ettingshausen.—Ed.]

[1] [Geologists now distinguish the oldest stratified beds from the superimposed Silurian as the *Laurentian* and *Cambrian systems*. They contain but few remains of organic life.—Ed.]

The former had a columnar unbranched stem, 20 metres in height, and rising from a square base 1 metre in diameter,



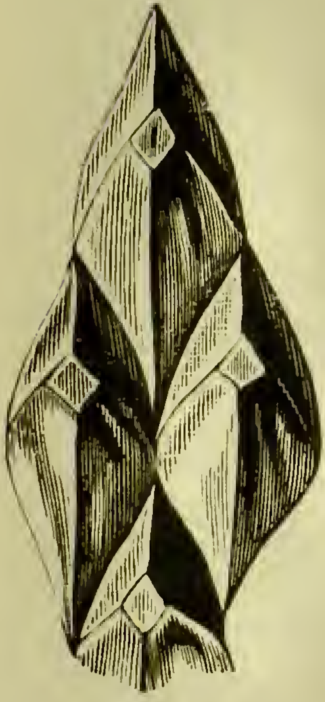


Fig. 536.— Leaf-scars ot *Lepidodendron elegans* (natural size).

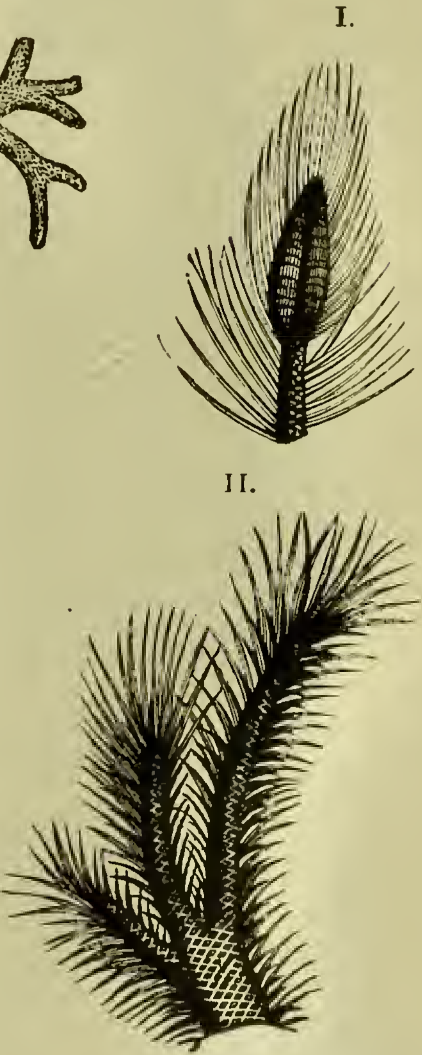


Fig. 537.—I. Fertile branch; II. terminal branch of *Lepidodendron* (reduced).

Fig. 535.—Branching stem of *Lepidodendron*, from the coal-beds of Bohemia (reduced).

the bark being covered with a number of longitudinal rows of diamond-shaped leaf-scars; [and it is now generally believed that the fossils known as *Stigmaria*, and formerly regarded as a distinct plant, are in reality the roots of Sigillaria.] The Lepidodendra, on the other hand, had much-branched stems, 30 or more metres in height, and 4 metres in girth, and

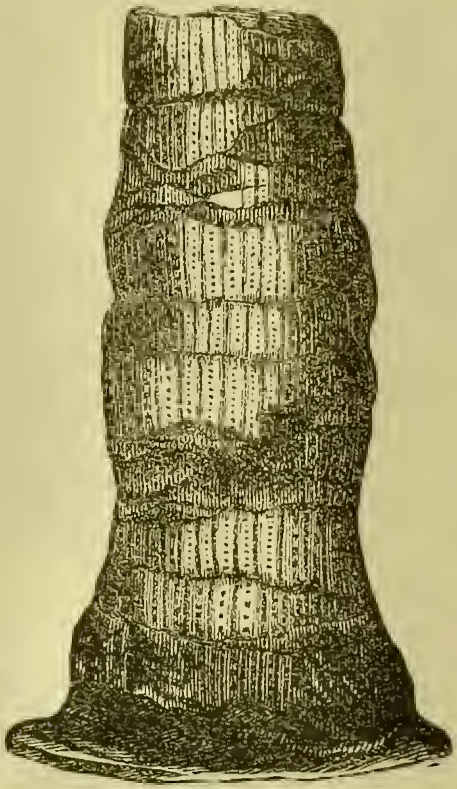


FIG. 538.—Stem of *Sigillaria*, from English coal-bed (reduced).

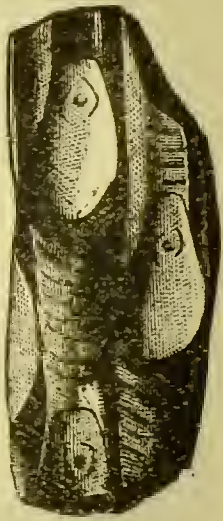


FIG. 539.—Leaf-scar of *Sigillaria Græseri* (natural size).

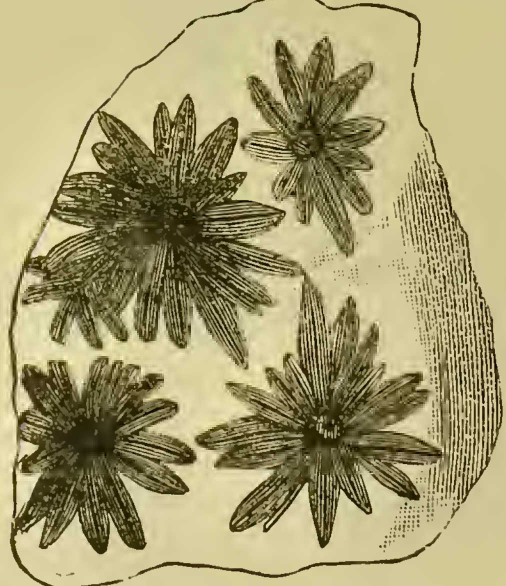


FIG. 540.—*Annularia fertilis.*

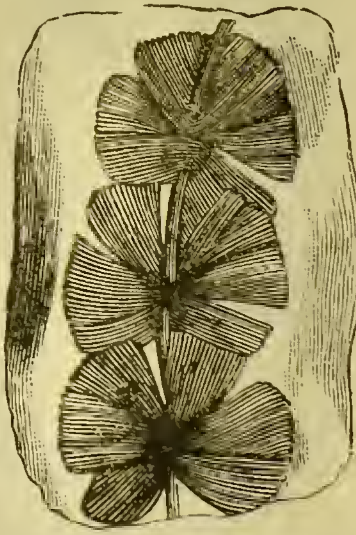


FIG. 541.—*Sphenophyllum annulatum.*

were also beautifully marked with scars. Associated with these were gigantic Equisetaceæ known as *Calamites*, of which those now existing are as dwarfish representatives as the Lycopodia are of the Sigillariæ and Lepidodendra. There existed, however, also in those forests—the true primeval forests of the earth—herbaceous plants (Ferns), such as *Annularia*, *Asterophyllum*, and *Spenophyllum*, as well as some Monocotyledons, Cycadeæ, and Coniferæ; and even the number of species was quite considerable. The Sigillariæ, Lepidodendra, Calamites, Asterophyllites, and possibly also the Tree-ferns, attained in this formation their maximum development; in the succeeding one their number diminishes. In connection with other plants, and perhaps also with sea-weeds, they form the valuable deposits of *coal*. In this form they have undergone sometimes more, sometimes less change, no trace of their vegetable structure

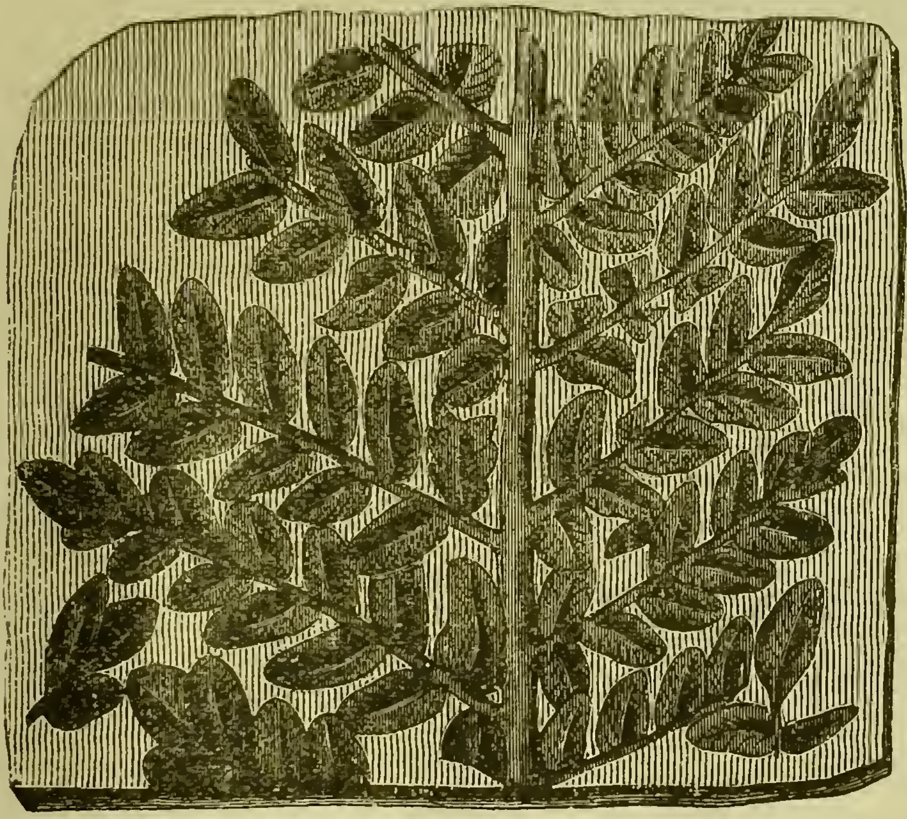


FIG. 542.—*Neuropteris heterophylla.*

often remaining, while the accompanying beds of earth receive their impressions, and preserve a correct image of them. It frequently happens, however, that entire stems have become fossilised (Fig. 534, p. 418), and still show their cellular structure in a wonderfully beautiful manner. We have no knowledge of the length of time during which the Carboniferous period lasted; but if it may be estimated from the thickness of the deposits of coal, many authorities would place it at millions of years.

It is impossible to suppose that deposits of coal occurred only in the Carboniferous period; they are found in almost all strata higher in the series, but in a different form. In the uppermost we find *peat*, the coal-formation of the present; below it is *lignite* or brown coal, bearing sometimes a greater resemblance to peat, sometimes to the true *coal* which lies beneath it. The origin of the latter from peat is therefore not improbable, and in some cases is unquestionable. The mode of formation of peat must therefore be first investigated. When Algæ and other plants grow undisturbed in perfectly stagnant water, to the bottom of which they fall quietly as they decay, the layer of organic matter thus formed grows gradually thicker and thicker; the reeds, rushes, sedges, and Equiseta retreat from the shore, the dense matting of their roots gradually advancing farther and farther on the muddy soil. Every year the dead leaves and stems of the water-lilies, water-Ranunculi, Potamogeta, and Lemnæ fall to the bottom; the mass of vegetable remains and the roots and rhizomes which penetrate among them become denser and denser, and more and more space is constantly taken from the water, until at length a densely interwoven substance results, resting on a soft layer of mud. Sphagna, Eriophora, marsh trefoil, Vaccinia, and other plants, establish themselves on this unstable foundation. The vegetable remains covered in this way, and protected against the action of the air, still decay, but not so completely; they are continually losing oxygen, hydrogen, and nitrogen, while the carbon accumulates. The mass is also increasing upwards; for long after the lower parts of the bog-mosses (Sphagna) which take an especially important part in these processes have died off, the upper parts still maintain a vigorous life, drawing up the water from below like a sponge. The substructure, which was at first very soft, becomes therefore gradually denser in the course of time, until at last a firm *peat-moss* is formed beneath the superficial vegetation. The ground is however constantly kept moist by the peat, and a luxuriant vegetation is hence developed on it, fed by the abundance of food-material which it contains. As soon as it becomes firmer, trees and shrubs, willows, alders, and buckthorns, spring up on it, and finally also conifers ; but the life of these larger plants is as a rule somewhat limited ; and when they are blown down by the wind or fall by their own weight, the peat-moss grows over them, and in the course of years they become entirely covered up by it. There, excluded from the action of the air, they do not decay, the structure of their wood being retained perfectly for centuries. This is the mode in which peat is formed.

Even in lignite the remains of plants can be abundantly recognised. This is less the case in true coal, and scarcely at all in anthracite, the hardest coal with most of a mineral character. It is often possible to determine the plants which have contributed to the formation of coal only from the fossils and impressions found in the accompanying beds of earth. The exclusion of the atmosphere, and the pressure, often immense, which beds of peat that have been flooded and buried beneath the surface have had to sustain from the superincumbent layers of earth, explain their transformation, first into lignite and then into true coal. In many beds of coal, as for instance those of Silesia, their origin from layers of peat is sufficiently evident ; in others this explanation does not seem to apply, and we must assume that drift-wood has been the source from which they were formed. Even at the present time the gigantic rivers of America tear down from their banks and carry away trunks of large trees ; and when these trunks have become completely saturated by water, they are left behind by the current, and sink either in an inland lake, at the mouth of the river, as in the Mississippi, or in the sea as drift-wood, and thus form immense deposits which may very easily be transformed into coal. But these trunks must retain some traces of their journeyings, and must be intermixed with the remains of water-animals, and, when the deposition takes place in the sea, of marine plants. These phenomena are in fact observed in many of the coal-formations of north Germany, the production of coal having taken place in the manner already indicated. The formation of coal from the deposition of successive layers of plants in primeval forests is very improbable.

It is remarkable that after the Carboniferous period the luxuriance of vegetation appears to have diminished. As if the earth were already exhausted, one form after another of the existing vegetation disappears ; and in the *Permian* series, only the lower strata, the *New Red Sandstone*, contain any quantity of plants, and then chiefly in a silicified state. The *Magnesian Limestone* which rests upon it contains but very few vegetable remains. The Permian has only one form in common with the lower, and only a few with the upper strata of the Carboniferous system. The prevalent forms are still Sigillariæ, Calamites, Ferns, Lepidodendra, &c.; but in addition are found Palms and Cycadeæ, the latter order attaining here their maximum development.

A different vegetation characterises the *Secondary* or *Mesozoic* strata. The forms characteristic of the Palæozoic beds, Sigillariæ, Lepidodendra, and Asterophyllites, disappear, and others make their appearance which bear a greater resemblance to those of the present day. The Coniferæ began in the Devonian, attained a maximum in the Carboniferous, and again diminished in the Permian system.

In the lowest system belonging to the Secondary strata, the *Trias*, Coniferæ must have formed the main part of the forests; while of Cryptogams, so largely developed in the lower rocks, only Ferns remain, those however belonging to new, and partly to peculiar and highly developed genera. The chief forms of Coniferæ in these forests were species of *Voltzia* (Fig. 543) and *Albertia*. The former were lofty trees, not unlike our *Cryptomeria*, while the latter had broad leaves penetrated by delicate longitudinal veins. With them are associated certain Cycadeæ (*Zamites*, Figs. 545, 546) and water-plants, as well as Calamites with verticillate leaves, and gigantic Equisetaceæ, which may have clothed the margins of the sheets of water. Of the three well-characterised sections into which the Trias is divided, the lowest or *Bunter Sandstein* contains but few vegetable remains, the middle or *Muschelkalk* scarcely any, and the uppermost or *Keuper* only a few. The flora of the Trias, in its gigantic Ferns and peculiar Coniferæ, bears a greater resemblance to that of New Zealand than of any other country at the present time.

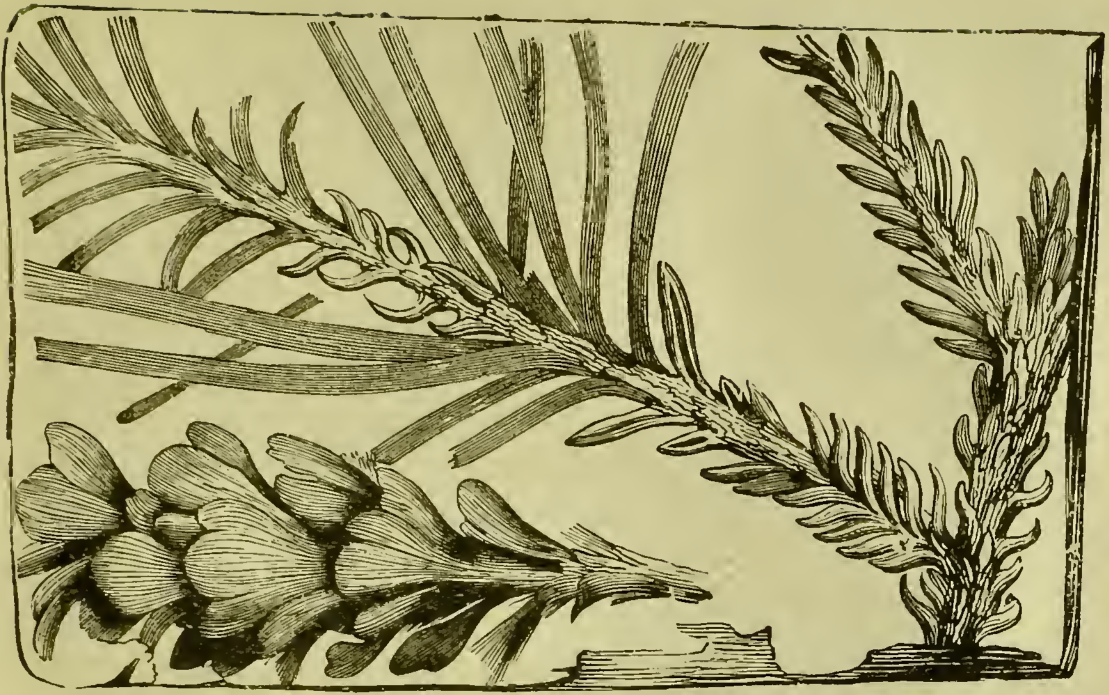


FIG. 543.—Terminal, middle, and fertile branch of *Voltzia* (*Schizoneura*) *heterophylla*, from the Vosges.

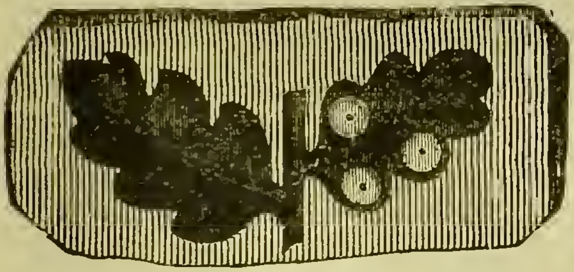


FIG. 544.—A fertile and barren pinna of a Fern-frond, *Goniopteris Murreyana.*

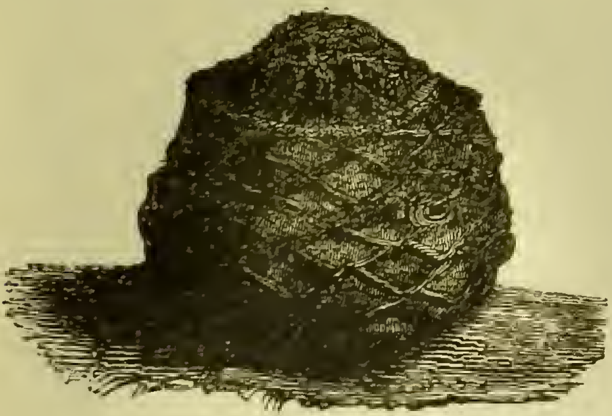


FIG. 545.—Stem of *Cycadoïdea megalophylla* (Cycadeæ), from Portland Isle.

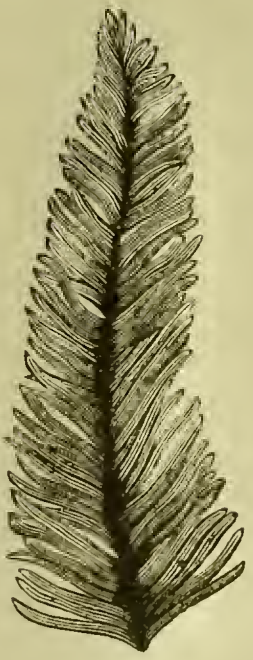


FIG. 546.—Branch of *Presleanum* (Cycadeæ).

The uniformity of vegetation characteristic of the Carboniferous is still more marked in the Triassic system.

Next in succession above the Trias is the *Jurassic system,* which again is divided into three sections, the *Lias,* and the *Lower* and *Upper Oolite.* The fossil remains found in this formation lead to the conclusion that the marine plants of the Lias did not differ essentially from those of the present time in their external appearance, although the species may have been very dissimilar. The case is different with the terrestrial vegetation, in which we still find a considerable coincidence with that of the Keuper. The prevalent forms in the forests consisted of Cycadeæ, of which fifty-eight species have been described. From this point, this beautiful form of vegetation, which in regard both to its habit and to its morphological and anatomical structure occupies an intermediate position between the Ferns, Palms, and Coniferæ, decreases, only a few species existing at the present time. With these were associated numerous Coniferæ nearly related in form to our *Araucarias* and *Thujas.* The underwood of the forest still consisted of Ferns, along with fleshy Fungi. The marsh-loving Calamites have disappeared, and the Equisetaceæ of that period scarcely exceeded our own in size. Plants allied to Typhaceæ, Naiadeæ, Cyperaceæ, and Juncaceæ, fringed the edges of the water. This sketch gives, however, only an imperfect idea of the vegetation of that system ; for its coal shows that in magnitude it must have resembled that of the Carboniferous period. The vegetation of the Lower Oolite presents no great difference from this. A number of sea-weeds have been preserved ; the earlier forms of Ferns and Cycadeæ disappear, and others take their place more nearly related to those of the present time. The flora of the Upper Oolite does not include any marine plants, only a single freshwater Alga, and in other families also fewer forms than the Middle period. There would seem to have been an exhaustion of the earth similar to that which apparently succeeded the Carboniferous period.

In the *Cretaceous system* appear the first dicotyledonous trees. The lowest strata contain mostly marine plants, sea-weeds and sea-grasses, with a few trunks of a species of cypress which floated on the sea in the form of drift-wood. The fossil remains of the Middle Cretaceous are much richer. The Cycadeæ diminish in numbers; but in their place appear the first exogenous trees, *Juglandites* and *Acerites*, related to our walnuts and maples. Among the Ferns, which had hitherto formed almost the entire undergrowth of the forests, rose shrubs allied to our willows; alders and horn-beams, *Alnites* and *Carpinites*, attained the size of trees; and we find also allies of our *Myrica* or sweet-gale. We have no certain knowledge of the existence of herbaceous Monocotyledons; but certain impressions which bear a resemblance to lilies or gingers make it probable. The marine and littoral plants of that system are similar in essential points to those of the Lower Cretaceous. The Upper Cretaceous, including the *Chalk*, affords only a very few vegetable remains, and those entirely of Algæ.

The lowest of the *Tertiary* or *Cainozoic* rocks are the *Eocene.* In this period dicotyledonous trees first begin to contest the supremacy with Cryptogams and Cycadeæ, and the entire outward form of the vegetation approaches that of our time. The lowest strata of this system furnish a marine flora consisting of sea-weeds. This is succeeded by a beautiful littoral flora, with Equisetaceæ, Characeæ, and Naiadeæ. Land-plants finally appear; and among these palms are especially conspicuous, and with them bananas, Myrtaceæ, Lauraceæ, and other exogenous and coniferous trees, which must, according to our present knowledge, have belonged to a tropical climate. Remains of the Ferns, Cupressineæ, and Cycadeæ belonging to this system have been found in Greenland in 70° N. lat. We know of no country at the present time which affords a similar grouping of plants to the flora of the Eocene formation, taken as a whole. That of the basin of the Mississippi probably presents the greatest similarity to it; but there are also points of resemblance to those of California, New Zealand, and Australia.

The next systems, the *Miocene* and *Pliocene*, are separated somewhat arbitrarily from the preceding and from one another, if the floras only of the formations be considered; the transition from one to another, and from these to the present, being quite gradual. We find, the higher we ascend in the Tertiary strata, an increasingly greater number of forms which indicate a cooler climate. The tropical plants gradually disappear, and are replaced first by subtropical forms, and then by those adapted to a temperate climate. Especially in the Middle Tertiary or Miocene system we find large masses of carbon deposited in the earth in the form of beds of 'brown coal' or *lignite.* It is evident that the German deposits of lignite are almost entirely composed of the remains of Coniferæ; while in the marls, the sandy, loamy, and argillaceous strata which accompany the lignite, a number of the impressions of exogenous leaves are always found. But these coniferous forests did not exhibit a dull uniformity, as is the case with those of the present time; there was, on the contrary, an abundant and cheerful variety of forms, as is seen even now in the forests of Canada and Asia, though not to so great a degree. There must also have been enormous quantities of resin exuded by some of these trees, genera resembling *Thuja* and *Cupressus*, the preserved stores of which are eagerly sought for; this resin, hardened by external conditions, being now known as *amber.* In addition to the Coniferæ already mentioned, we find, in what appears to be near the close of the Tertiary period, that the forests of northern and central Europe consist largely of dicotyledonous trees—oaks, beeches, birches, alders, and willows. Plants belonging to the Primulaceæ, Scrophulariaceæ, Crassulaceæ, and other existing orders, sprung from the ground beneath the trees, covered with moss and fungi, and adorned with Rhododendrons, Azaleas, and other beautiful bright-coloured Ericaceæ. Species of honeysuckle formed bushes or climbed up the trees, on which grew parasitic plants allied to our mistletoe. In Italy are found the remains of species of *Salisburia* and *Liriodendron*, the allies of which now grow only in Japan and South America. Many species of these recent formations probably exist to the present day. Up to the year 1853, Goeppert had described the remains of 162 plants belonging to 64 genera preserved in amber; 30 of these he recognised with certainty as belonging to the present time, while others do not admit of a perfect identification.

The *Post-pliocene*, *Pleistocene*, or *Alluvial* formation includes deposits believed to be formed immediately before the historic period. It is to these strata that the remains of the mammoth, mastodon, and other gigantic animals belong; but the number of species of plants found is only small, and these have only been partially determined with certainty. How unequal has been the preservation of the remains of this period is shown by the circumstance that our only source of knowledge of the existence at that time of our pines and arbor-vitæ is the fact that the remains of food found in the hollow teeth and stomachs of mastodons which had become enveloped in ice belong to these plants.

From these Alluvial formations we pass to the present age, with its forests, meadows, steppes, deserts, seas, lakes, and marshes, each of which has its peculiar flora and its special physiognomy. Among the endless variety of species of plants by which this latter is determined there are a certain number of leading forms which arrest the attention of the observer. Among these are Hymenomycetous Fungi, Lichens and Algæ, Mosses and Lycopodiaceæ, Ferns and Equisetaceæ, Coniferæ, Cycadeæ and Palms, Grasses, bulbous plants, Agaveæ and Aloïneæ, Scitamineæ and Musaceæ, Aroideæ, Orchideæ, lianes,[1] Casuarinaceæ, willows,

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[1] Climbing or twining plants, mostly tropical, and often with tendrils, Passifloraceæ, Bignoniaceæ, Aristolochiaceæ, reeds, palms, &c.,

Cupuliferæ, Ericaceæ, Myrtaceæ, Melastomaceæ, Lauraceæ, Compositæ, Umbelliferæ [Labiatæ, Cruciferæ, Primulaceæ], Cactaceæ, arborescent Euphorbiaceæ, [Mesembryanthemaceæ], [figs], Malvaceæ, Mimoseæ, and Nymphæaceæ.

CHAPTER VIII.

BOTANICAL GEOGRAPHY.

Botanical Geography treats of the distribution of plants on the surface of the earth ; it collects the plants of any particular country into a Flora, and investigates the causes, operating either at the present time or in the past, which have led to each species acquiring its special habitat, and have resulted in only a few plants—termed cosmopolitan—becoming distributed over the whole globe, or even over a large part of it.[1]

The earth does not everywhere produce those plants which are especially adapted to each particular region. If this had been the case, the same species would be constantly met with in widely separated countries that enjoy a similar climate, and no immigration of foreign plants would take place, such as often happens before our eyes. Each species has, in fact, become disseminated only at particular spots ; it has its centre of distribution at the spot from whence it originally sprang ; but the limits of these centres are often obscure, because plants have found conditions suitable for their existence outside these bounds, and

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feebly represented by our grape-vine, ivy, hop, honeysuckle, [Convolvulus], &c.

[1] The phyto-geographical map at the end of the volume must be consulted in connection with this chapter. It indicates the boundaries of the twenty-four phyto-geographical regions adopted by Grisebach in his ‘Vegetation der Erde,’ each region being coloured uniformly. The regions of a more generally wooded character are coloured green and dark blue, the steppes and deserts yellow and red, while those regions which have no special character of their own are of some other colour. [The statements of Grisebach—on whose work the whole of this chapter is founded—are somewhat too unqualified, both with regard to the boundaries between the regions and to the characters which distinguish them from one another.—Ed.]

have thus occupied more and more ground by migration. All plants are, however, not equally capable of migration ; if this were the case, the strongest would everywhere have replaced the rest, and have occupied the whole of the space devoted to vegetation. The unlimited distribution of plants is also prevented by seas, deserts, mountain-chains, differences of climate, and even by the existence of other plants and animals.

A natural flora results from the interchange of a number of forms belonging to different centres of vegetation, and their union into a whole with definite characters. The limits of such a flora are determined by climate, or by the hindrance to the distribution of species afforded by a broad ocean or other obstacle ; and these floras are the more natural the more sharply they are defined, and the less their aboriginal inhabitants have mingled with immigrant forms. The most effectual hindrance to this intermingling is presented by the ocean. Almost as completely the great Sahara separates the flora of tropical Africa from that of the Mediterranean region ; and the forest-region of equatorial America is an insurmountable obstacle to the migration of the native plants of the grassy plains of Venezuela and Brazil. The chief factor, however, in the separation of floras is difference in climate.

The comparison of different floras, and of the regions to which they belong, brings out the law that the species of a genus or the genera of an order are the more nearly related to one another--in other words more closely resemble one another—the less the distance between their centres of distribution, or the more similar the climates of these centres. It is scarcely possible, for example, to have greater differences of climate than those which subsist between the base and the summit of lofty mountains ; and yet the vegetable productions of the most elevated regions not unfrequently bear the closest systematic relationship to those of the warm valleys out of which the mountain rises ; a phenomenon which suggests the supposition that the plants of the heights have ascended from the valleys, and have adapted themselves to the new vital conditions as far as was necessary to their perpetuation. But the transitions from one species to another which might be expected in the gradually ascending mountain regions are most commonly wanting ; the Alpine species make their appearance, and those of the plains disappear, suddenly, at particular elevations. Contiguity of locality is, however, except in the case of mountain-ranges, usually accompanied by resemblance in climate. But there are also resemblances of climate without geographical contiguity ; and allied genera or species appear in the most widely separated regions, if their climate is similar. Well-known examples of this fact are furnished by the beeches of Japan and the Straits of Magellan, and by the heaths of the Cape of Good Hope and of western Europe.

Since one of the main problems of phyto-geography is the investigation of the means by which a plant ensures its existence, a physiological system may be contrived, according to the plan proposed by Humboldt, in which those organs of a plant which serve for the maintenance of its life—in other words its habit—are first taken into account; these characters determining to a great extent the natural features of the vegetation. A certain connection can indeed usually be recognised between the external form of the vegetation and the climatal conditions which determine its geographical distribution. On this plan the vegetable kingdom may be divided into the seven following classes:—1. Woody plants; 2. Succulent plants, such as the cacti; 3. Climbing plants (lianes); 4. Parasites or epiphytes, like the mistletoe; 5. Herbaceous plants; 6. Grasses; 7. Cellular plants; and each of these groups may be divided into a greater or smaller number of sections.

In order to obtain an idea of the entire vegetation of the globe, the surface of the earth has been divided by Grisebach into twenty-four natural floras, or *regions of vegetation.* Each of these floras is again subdivided into zones, the phyto-geographical character of which is determined by its elevation above the sea-level; a succession of zones being thus obtained, until at length the line of perpetual snow sets a limit to almost all vegetable life.

The determining conditions and the actual boundaries of these floras are, however, at present but imperfectly known, [and, indeed, any such division must be considered as very inadequately representing the endless variety and complexity of nature. In all such classifications there is a definiteness and sharpness of outline, which is really an inherent logical defect of all classifications of natural phenomena, rather than a representation of anything that has an exact counterpart in nature]. The districts characterised by the occurrence of similar forms and often identical species, occupy as a rule lower zones of elevation with an increase in the latitude [north or south], and advance from elevated regions in lower latitudes to less elevated regions in higher latitudes. Thus a number of species of the Swiss and Italian Alps occur at a much lower elevation on the mountains of Norway and in Lapland; and plants found above the snow-line on Mont Blanc belong also to the Arctic flora. The floras of mountain and of Arctic regions nevertheless exhibit some considerable differences.

At the base of the mountains of the equatorial zone, from the sea-coast to the height of about 630 metres, the external conditions, and therefore also the character of the vegetation, are similar to those of the plains. This is the zone of palms and bananas. It is followed, as far as a height of 1,300 metres, by the zone of tree-ferns and figs. In India these lofty trees are covered by multitudes of Piperaceæ, Aroideæ, and Orchideæ. In the islands of the southern ocean the figs are replaced by arborescent Urticaceæ; and the valuable Cinchoneæ are characteristic of the South American region. In the zone of myrtles and laurels, which succeeds as far as a height of 1,900 metres, trees with thick shining leaves are predominant, Myrtaceæ, Camelliaceæ, Magnoliaceæ, and others; but the Acacias and Ericaceæ also attain here their maximum development, and evergreen oaks are very abundant. The laurels occur especially towards the upper limit of this zone, and are found also abundantly in the next, that of evergreen trees, which extends from about 1,900 to 2,500 metres. Next comes the zone of trees with deciduous foliage, which extends to a height of about 3,200 metres, and under the tropics is seen only on the elevated plains; and a luxurious arborescent exogenous vegetation scarcely reaches beyond 2,800 metres. At this point a variety of Coniferæ make their appearance, such as with us are intermingled with the exogenous trees. From 3,200 to 3,800 metres is the zone of Coniferæ, and from that to 4,500 metres that of Rhododendrons. Lofty trees now disappear, and are replaced by luxuriant meadows and pastures, among the brilliant herbaceous vegetation of which Rhododendrons and Azaleas are conspicuous, not only by their shining coriaceous leaves, but also by their magnificent clusters of flowers, often of gigantic size. The eighth and last zone, that of Alpine herbs, extends from the elevation of 4,500 metres to the limits of perpetual snow. Here are found chiefly low-growing perennial plants with woody roots, a small amount of foliage, and comparatively large brightly-coloured flowers; and almost all the herbaceous plants are marked by containing resinous and bitter substances.

The Alps and other mountains of Central Europe possess, on the other hand, only six phyto-geographical zones. The zone of fruit-trees, that of the spurs of the mountains, rises on an average to about 660 metres. The apple and the grape-vine usually ascend to this elevation, while the walnut reaches as high as to 1,000 metres. In this zone the vegetation of the plain is predominant; the woods consist mainly of beeches, birches, alders, larches, and pines, and the upper limit of the oak occurs here. The zone of beeches, or the lower mountain zone, extends in the Alps to a height of 1,500 metres, in the Sudetes of Silesia to 1,000, and in the Hartz mountains only to 600 metres. The birch, the sycamore, the service, the hazel-nut, the wild cherry, and many herbaceous plants, such as species of *Lamium*, *Plantago*, *Artemisia*, *Taraxacum*, *Asperula*, and *Chrysanthemum*, attain their upper limit here, and disappear with the beech. At the same time we reach the lower limit of *Rhododendron*, *Gentiana*, *Primula*, &c. The zone of pines, or the upper mountain region, reaches in Switzerland an elevation of 1,800, in the Sudetes of 1,500, and in the Hartz mountains of 1,000 metres. Here we have the upper limit of the spruce fir and larch, while the Rhododendrons attain their maximum development. *Pinus Mughus* and *Cembra* form great forests in this zone of the Alps, extending also into the next in succession, the lower Alpine region. This ascends to the upper limit of *Pinus Mughus*, an elevation of about 2,300 metres. In the granitic Alps of Switzerland this tree is often replaced by the green alder. This is also the highest limit of animal life in the Alps; only a few species being found at a greater height. The zone of Alpine herbs, or the upper Alpine zone, extends to the limit of perpetual snow, 2,800 or 3,000 metres. Of woody plants this zone has only the dwarf willows, with perhaps a few Rhododendrons, the beautiful mountain heath, *Erica carnea*, and the single Azalea found in the Alps, *A. procumbens*. In the zone of Cryptogams, or the snow region, above the limit of perpetual snow, all phanerogamic vegetation has disappeared ; only Mosses and Lichens are still found, and the 'red-snow,' *Protococcus nivalis*, temporarily colours the white tracts of snow.

It will illustrate how the distribution of plants in altitude is modified by local circumstances, to mention that in the northern Alps the upper limit of the cultivation of the grape-vine is 500 metres, in the central Alps 600, while in the groups of Monte Rosa and Mont Blanc it ascends to 900 metres.

REGIONS OF VEGETATION.

1. *The Arctic Region.*

The Arctic flora embraces those regions of the extreme north which lie beyond the polar limits of the forests. Its character is determined by the shortness of the period of vegetation, and the comparatively low temperature during this period. The plants belonging to it must be able to undergo a period of hibernation of at least nine months each year. The portion of them which rises above the surface is comparatively small, and their underground stems are almost always perennial ; annual plants are almost entirely wanting. Hepaticæ, Lichens, Grasses, and Cyperaceæ, a few shrubs and sub-shrubs—willows, birches, and Vacciniaceæ—as well as evergreen Rhododendrons and Andromedas, form the flora characterised [in part] by the size and brilliant colour of its flowers. There are no cultivated plants. In this region occur the 'Tundren,' broad plains covered with Mosses and Lichens. The Mosses are partial to moisture, and hence form the 'moist Tundren ;' the brown, black, gray, or yellow Lichens grow, on the contrary, on the sandy products of the decomposition of masses of granitic rock, and form the 'dry Tundren.' These latter furnish food for animals, and are therefore more valuable than the former.

2. *The Europæo-Siberian Forest-Region.*

The general climatic character of this region, which gives rise to the uniform nature of its vegetation, is the uniform average temperature of its entire vegetative period, and the absence of a rainless season to interfere with the growth of its trees. Combined with these is a condition peculiarly favourable to its arboreal vegetation, a period of activity always amounting to more than three months in each year, which distinguishes it from the Arctic Region; while the permanent moisture of the ground from constant rainfall, separates it from the steppes which lie to the south and from the Mediterranean district.

On the borders of the ocean, especially on the Atlantic coasts, the sea produces an effect on the climate, moderating both the cold of winter and the heat of summer, and thus producing a mild maritime climate, in contrast with the more widely extended continental climate. The longer duration of the period of vegetation, and the gradually increasing temperature of the summer, are noticeable in passing through this region from north to south.

There are also large tracts of country in which the forests have been made to yield to cultivation, and which render the general term for the region somewhat inapplicable. This clearing of the forests in Europe has also made the climate more continental by diminishing the rainfall. This destruction of forests alters the climate, not only because the trees shade the ground and hence keep it cooler, but also because they retain in the soil and in their tissue larger quantities of moisture, which are gradually restored to the atmosphere by transpiration.

Dependent on these conditions, the whole of this forest-region from the Atlantic to the Pacific Ocean may be divided into seven zones :—1, the French zone of the sweet chestnut ; 2, the German zone of *Pinus Picea* ; 3, the Hungarian zone of *Quercus Cerris* ; 4, the central Russian zone of exogenous forests ; 5, the northern zone of Coniferæ ; 6, that of *Quercus mongolica* ; and 7, that of *Betula Ermani*.

Among all the forest-trees of Europe the beech is the most characteristic of a maritime climate ; but the zone of the beech passes gradually into those of the chestnut, *Pinus Picea*, and *Quercus Cerris*. These three zones correspond to particular districts of the maritime climate characterised by the difference in mean temperature between the coldest and warmest months of the year. In the first zone, the mean monthly temperature varies between 12°·5 and 17°·5 C. ; in the second between 17°·5 and 22°·5 ; and in the third between 22°·5 and 23°·5 C. The characteristics of the central Russian zone of exogenous trees, of the northern zone of Coniferæ, and of that of *Quercus mongolica*, depend on their continental separation from the influence of the ocean. The broad girdle of forests of the Russian lowlands, which consist mainly of oaks, is limited on the north by the decreasing temperature, on the east by the insurmountable barrier of the Ural mountains. To the north of it is found therefore a belt of Conifers—pines and larches—accompanied by birches, which reaches to the Arctic Region, and across the Ural through Siberia, till at length it reaches the Amoor and the sea-coast of Ochotsk. The zone of the Amoor or northern Mantschuria has a completely continental character. The trees, among which *Quercus mongolica* is the most characteristic, belong for the most part to European genera, but to peculiar species ; the Siberian Coniferæ occur here only on the mountains. The last zone, that of *Betula Ermani*, owes its peculiarity—a long period of vegetation with a diminished summer temperature—to the neighbourhood on the one hand of Siberia and on the other hand of the sea.

Among the cultivated crops of this region the most remarkable are the potato, apple, grape-vine [and the cereal grasses]. Of the latter barley extends the farthest to the north, accompanied by the potato. In Europe generally the cereals vary with the geographical latitude; barley in the north, then rye [and oats], and wheat in the southern parts. The apple and grape-vine, on the contrary, are more dependent—at least at their northern limits—on direct sunshine, and in consequence flourish there only in the most sunny localities. Special mention must be made of the turf-forming grasses, and the meadows which they produce, found to the same extent in none of the neighbouring regions; heaths, moors, and alder-fens are also almost peculiar to this region.

3. *The Mediterranean Region.*

The most important peculiarities of the climate which determine the flora of this region are the rainlessness of the summer and the mildness of the winter. While, therefore, in the forest-region the chief development of vegetation takes place in the warmer portion of the year, in the countries which border the Mediterranean, on the contrary, plants grow during the spring, remain stationary during the dry period of summer, and renew their growth under the influence of the autumn rain. This peculiarity shows itself on the mountainous border of the region, and in the neighbourhood of the Sahara; but is fully developed only on the shores of the Mediterranean. The flora of the elevated plains and mountains indicates an approximation, sometimes to that of the steppes, sometimes to that of the forest-region, sometimes to Alpine and Arctic forms.

Agriculture has here this advantage; that the same plot of ground will produce several crops in one year, but often only by carefully regulated irrigation. The olive is a specially characteristic product of this region; the further one advances south, the greater is the number of plants cultivated for food or for some other useful quality. Along with cereals, the grape-vine and olive, are found the mulberry, maize, millet, rice, water-melon, orange, fig, cotton, and even the date-palm, sugar-cane, plantain, and batatas. Many of these plants, as well as the Indian fig (*Opuntia*), agave, and aloe, grow in this region only under cultivation. One of its peculiarities is the great abundance of evergreen trees—the laurel, myrtle, oleander, olive, evergreen oak, &c.—as well as of thorny shrubs. These latter often cover wide tracts, to the exclusion of almost all other vegetation, frequently forming dense thickets.

4. *The Steppe Region.*

This region stretches from the mouth of the Danube to the affluents of the Amoor; from the central Volga to the coast of the Persian Gulf and the crests of the Himalayas. The gradual rise of the ground from the basin of the Caspian Sea to the Asiatic highlands neutralises the approach towards the equator, amounting to 27° of latitude. Throughout this immense region there prevails a uniform alternation of three periods in the year; the severe and protracted winter is followed by a short spring, and this by a rainless burning summer, which is succeeded almost immediately by the snow-fall of winter. It is only the short spring that is favourable to the growth of vegetation. The peculiar plants of the steppes have therefore, in some cases, a short existence, in others special means of protection against the drought of summer. Among the most characteristic forms of vegetation are plants with bulbous underground stems, yielding a volatile oil, or covered with spines or hairs. The different kinds of steppes—grass, salt, and sand—maintain peculiar forms of vegetation; trees, or even shrubs, occur only where vegetable life is aided by abundance of water or artificial irrigation. Of cultivated plants, rice, cotton, and sesame thrive ; but fruit-trees need protection against the cold of winter.

5. *The Chino-Japanese Region.*

The Chinese lowlands, including the Japanese archipelago, have the advantage over Europe of a more regular distribution of the rainfall. This is in consequence of the monsoons, which extend as far as 40° or even 45° N. lat., and cause a rainy period in the spring. The extremely regular succession of seasons which results is favourable to a careful garden-like agriculture, the chief crops being wheat, cotton, indigo, the sugar-cane, and orange, but especially rice, the mulberry, and the tea-tree. There are no meadows or fodder-crops. The aboriginal vegetation has been driven back to the highlands. A characteristic of the native flora is the large number of trees and shrubs, many of them, like the Camellia, evergreen.

6. *The Indian Monsoon Region.*

This region is not characterised by any special climatal conditions, but only by the general phenomena of the tropics. Growth takes place exclusively in the rainy season. Accordingly as the monsoon is a land- or a sea-breeze, is it dry or moist ; and the monsoon region, in fact, includes every description of climate which is possible within the tropics. On its northern border, for example, its conditions approximate to those of the temperate zone ; and at the foot of the Himalayas there is an immediate transition from the desert landscape to the most luxuriant tropical forests. Besides the gigantic forests, characteristic forms of vegetation are presented by the savannahs and the jungles. Among the prominent features of the flora of this region are palms, bamboos, and tree-ferns ; the banyan, *Ficus indica*, which emits aërial roots from its branches to the ground ; mangroves, which put out roots from the seeds while they still remain in the fruits attached to the branches, and thus, like the banyan, can produce a group of trees from a single individual; laurels, teak-trees, lianes, numerous beautiful Orchideæ, Nepenthaceæ, and Nymphæaceæ. The most important food-plant is rice. Cotton, the opium-poppy, ginger, sesame, and indigo are also widely cultivated crops. Among fruit trees and useful shrubs, the coffee-plant is grown in Java, cinnamon in Ceylon, the nutmeg and clove in the Moluccas, the bread-fruit and the cocoa-nut-palm in the South Sea Islands, camphor in Borneo, pepper in Malabar and Siam. In addition the plantain, orange, and other sweet fruits are universal.

7. *The Sahara.*

This is the region of the unchecked prevalence of the trade-winds in northern Africa, northern Arabia, and southern India, and is almost rainless. Any vegetation is possible only from the occasional occurrence of thunderstorms or dew, or from the rainfall of adjoining regions being carried underground as surface-water, and giving rise to springs or wells. But it is scarcely conceivable that there are even in the Sahara any large tracts in which a scanty vegetation cannot thrive at certain times. The nature of the surface indicates four varieties of landscape:—the stony plains of the Hammada; the undulating deserts of the Areg covered with shifting sand; the deep gullies or Wadis; and the Oases. The Hammada brings forth only at particular spots scanty thorny or leafless shrubs, and sometimes also saline plants. The Areg sometimes produces Grasses. The rest of the scanty vegetation of the desert, oily and bulbous plants, &c., retreats to the Wadis and the Oases with their date-palms. The date-palm is the only tree which has its original and uncontested home in the Sahara; the rest, as well as a number of other plants, have migrated from elsewhere or been introduced by man.

8. *The Sudan Region.*

This region includes Central Africa from 20° N. lat. to 20° S. lat., as well as southern Arabia; and enjoys, in general, a refreshing rain only when the rays of the sun strike vertically downwards, remaining at other times under the influence of the dry trade-winds. Growth is therefore possible only as an occasional phenomenon; and the prevalent character of the vegetation is that of the savannahs. Copious dew and sharp changes of temperature contribute to render the climate of this region extremely ill-adapted for the immigration of foreign forms; so that the aboriginal fauna and flora have been preserved in their primitive aspect. A characteristic feature is the gigantic Grasses, often 6 or 7 metres high; peculiar to it are the enormous stems of the baobab and leaves of *Musa Ensete*. Among the more important useful plants are the tamarind, the fig-sycamore, the palms, especially the doom palm and the oil palm *Elaeis guineensis*, and the succulent and poisonous arborescent Euphorbias. Acacias and thorny shrubs are generally distributed. A not inconsiderable portion of the Sudan flora has migrated into Upper Egypt. South Arabia was at one time treated as a separate region, on account of its balsamic vegetation.

9. *The Kalahari Region.*

The Kalahari region extends along the Atlantic coast of Africa from 20° to 29° S. lat. It is altogether destitute of water, and forms a connecting link between deserts, savannahs, and steppes covered with shrubs; and has no oases with a settled population, but is tenanted only by wandering nomads. Peculiar to this region is the remarkable *Welwitschia* (see p. 338); and the most prominent members of the scanty flora are spiny Acacias and other shrubs which almost entirely impede locomotion, a number of bulbous and tuberous plants, Grasses, and the south African water-melon. There are no palms.

10. *The Cape Region.*

The interior elevated plains of the Cape of Good Hope, which lie south of the Orange River, slope downwards through rocky mountains or precipitous descents to the level of the sea. The climate may be compared to that of the elevated plains of Spain. In both districts an extraordinary variety of vegetation is promoted by the unequal distribution of temperature, of the annual rainfall, and of the humidity of the air. The highest terrace (about 1,000 metres above the level of the sea), the Roggefeld, is at times completely bare, and at other times is covered only by small compositous bushes. The middle terrace, the Karroo-plain (700 metres), is also clothed with a uniform steppe-vegetation ; the so-called 'rhinoceros-bush' (*Stoebe rhinocerotis*) belonging to the Compositæ, covers the widest tracts of country ; it is only in August that the soil becomes clothed for a few weeks with a luxuriant green, carpeted with numberless flowers, belonging to the Compositæ, Liliaceæ, Mesembryanthemaceæ, &c. From the Karroo-plain to the coast the character of the vegetation is determined by the evergreen shrubs, constituting what is called the 'bush.' This is perhaps the richest spot on the whole earth in species of plants, and is especially the paradise of flowers. Ericaceæ, Proteaceæ, Euphorbiaceæ, Stapelias, Liliaceæ, Irideæ, and 'everlastings' (*Helichrysum*, belonging to the Compositæ) are the most conspicuous elements of the vegetation. Especially noteworthy is the *Prionium* or palmet (Juncaceæ), the stems of which grow so closely crowded together that they detain and impede the courses of rivers like wears.

11. *The Australian Region.*

Northern Australia has a tropical climate with a summer rainy period. In the sub-tropical zone, from 19° to 29° S. lat., is a desert belt in which the reign of the trade-winds is uninterrupted. The climate of South Australia may be compared to that of the Mediterranean, the rainfall being limited to the winter; while in Tasmania rain falls at all seasons. Most of the rivers are dried up for considerable periods, and leave gradually diminishing 'creeks' of water only where their beds are deepest. Woody savannahs termed 'grass-lands,' and thickets of bushes known as 'scrub,' occupy the greater part of Australia so far as it has been opened to colonisation. The grass-land is a carpet of meadow interspersed with occasional forests of *Eucalyptus*, and adorned in the rainy season with numerous bulbous plants, Liliaceæ, Orchideæ, &c., and 'everlastings.' The scrub consists entirely of densely interwoven shrubs, Proteaceæ, Epacrideæ, Myrtaceæ, Leguminosæ, &c., among which rise sometimes lofty trees, Eucalypti and Acacias; but is destitute of herbaceous plants and grasses. In the valleys of the creeks there is only a dense scrub; and here, among other plants, are found the Casuarinas (she-oaks), palms, and the grass-tree, *Xanthorrhœa*. In addition, Australia has also, like the Asiatic steppe-region, grass-, salt-, and sand-steppes.

12. *The North American Forest-Region.*

The regions of vegetation of North America correspond to those of the eastern hemisphere. A broad forest-zone passes through the whole continent from Behring's Strait to Newfoundland, and southwards as far as Florida and the mouths of the Mississippi. The narrow strip of coast of California may be compared with the Mediterranean region in its rainless summer period; and the Asiatic steppes correspond to the prairies between the Sierra Nevada and the Mississippi.

As compared with the Europæo-Siberian, the American forest-region is colder in the same latitude, and the difference may be estimated as, on an average, one of 10° of lat. Thus, for example, the average annual temperature at New York, in 41° N. lat., is 10°·5 C.; and that of Brussels, in 51° N. lat., is 10°·4 C. The difference is less than this in the southern portions, but increases gradually towards the north. The temperature diminishes very rapidly as we advance northwards, the cold waters of the Polar sea having no sufficient outflow southwards through the narrow Behring's Strait and Hudson's Bay. Europe has also the advantage of a less variable maritime climate, from the inland seas penetrating to a greater depth. In consequence of this, New York has the summer-temperature of Rome and the winter temperature of Copenhagen; Quebec the summer of Paris and the winter of Petersburg. The character of the vegetation is determined by this alternation of summer and winter temperatures.

The northern belt includes the zone of *Pinus alba* and *nigra*, which in America replace the European firs. Coniferous forests, the individuals of which are often of an immense size, mixed with a few exogenous trees, mark, in the zone of the Oregon pine, the passage to that of deciduous exogenous trees. These forests are distinguished from the corresponding oak- and beech-zones of Europe by the greater variety of their oaks, and by the species of elm, ash, and maple. The forest-zone of the Southern States is, as in South Europe, characterised by evergreen exogenous trees intermixed with representatives of tropical families. In its moist summer the climate of these States resembles that of China; the most noticeable crops are cotton, rice, and the sugar-cane. But these advantages are again partially counterbalanced by the sandy and marshy nature of the soil from Louisiana to Virginia, [the Great Dismal Swamp], covered by *Pinus australis*, and by the almost inaccessible swampy lowlands of the Atlantic coast.

Most European crops thrive in North America as well as with us; but the great alternations of temperature are unfavourable to the more tropical species, as the orange. The maize is cultivated to higher latitudes than in Europe, while the cultivation of the grape-vine is scarcely anywhere carried on with much success.

13. *The Prairie Region.*

The prairies, the steppes of North America, are treeless plains, in which the severe cold of winter is succeeded by a short period of active growth ushered in by a transitory rainy season, and a dry rainless summer. The cause of the summer drought is the dryness of the prevalent western Pacific winds; and this is the result of the moisture of the air being previously withdrawn by the Rocky Mountains and the chain of mountains along the Californian coast. The heavy rains which fall on these mountains are, it is true, the feeders of great rivers which cross the prairies; but these water-courses, which are often of great size, the affluents of the Mississippi, the Colorado, and the Rio Grande del Norte, are of but little service for the irrigation of the soil, because they have worn their way down into the soil, often to such a depth that no arable land is left in the deep chasms or river-beds known as 'cañons'; and sometimes there is not even a belt of trees by the side of the stream. The south-western portion of the region is covered by an inhospitable salt-desert, where the soil is often completely bare, or produces a vegetation consisting almost entirely of a few sparse Chenopodiaceæ and social Artemisias. There are, however, here and there in the prevailing desert, a few scattered oases, among which that of the Great Salt Lake is the most important. A contrast to the salt-desert is afforded by the northern portion of the region, a true grass-steppe, the home of the bison; while in the south agaves, aloes, and yuccas abound, and the Cactaceæ attain their maximum development. The few trees and shrubs which are found here and there on the banks of the rivers and slopes of the mountains have mostly migrated from the forest-region. Among the characteristic forms of vegetation are the Mimoseæ, especially the genus *Prosopis*, which forms by itself the feature in the landscape known as 'mezquit,' while, associated with other thorny shrubs, it constitutes the 'chaparals.'

14. *The Californian Region.*

The climate of this strip of coast, which is of a purely maritime character, is determined by the uniformity of the temperature—that of summer and winter differing by only a few degrees—and the regular alternation of a moist cooler season with a rainless summer. In the mildness and short duration of the winter, in the rainless summer of the forest-region beyond the Oregon, and—in contrast to the prairies—in the length of the period of active growth necessary for the development of arborescent vegetation, the climate of California resembles that of the Mediterranean, although the mean temperature is not so high. The culture of the vine has struck root here, and that of cereals and fodder-crops yields in places extraordinary results. Arboreal vegetation here attains its maximum development in the gigantic mammoth-trees, the *Sequoia* [or *Wellingtonia*] *gigantea*, the loftiest of known trees. Other gigantic though somewhat less lofty conifers, and evergreen exogenous trees, oaks, limes, ashes, and willows, shrubs allied to the oleander, myrtle, and heaths, as well as numerous smaller bushes and grasses growing in great masses, complete the flora of this small but remarkable region, which often assumes a park-like character.

15. *The Mexican Region.*

This region may be divided, according to its elevation above the sea-level, into three zones:—the gulf-zone, the zone of the Mexican highlands, and the Pacific zone. The first, a narrow strip of coast, rises above the dry sea-shore in gently sloping grass savannahs, interrupted here and there by woody tracts, and even by groups of palms. A much richer vegetation of tropical growths fills the moister ravines, the 'barrancas,' which score the volcanoes on all sides. The upper portion of the tropical zone is covered by damp mountain-woods with evergreen foliage. Associated with the lofty exogenous trees are tree-ferns, arborescent Liliaceæ, numberless lianes, among which are the sarsaparilla and the vanilla, an immense variety of copiously flowering Orchideæ and Bromeliaceæ, including the pineapple. The cultivation of the coffee, plantain, and sugar-cane are here carried on with success. A striking contrast to this wealth is presented by Yucatan, the chief product of which is its logwood forests. The highland of tropical Mexico enjoys an extremely uniform climate, with a temperature resembling that of the summer at Paris. In the character of its vegetation, its agaves, spiny Mimosas, and cacti, it approaches the southern prairies, but is admirably adapted to the cultivation of the olive, mulberry, and vine, and especially of the agaves which yield the drink known as pulque. The forests consist chiefly of oaks and Coniferæ. The gradual slope of Mexico towards the Pacific, or Pacific zone, has a less uniform character than the narrow Gulf-zone. Its flora is less rich than that of the Gulf-zone, the rainfall being less; but the sea-coast is bordered by a tropical forest which yields logwood and the cocoa-nut.

16. *The West Indian Region.*

The West Indies form a phyto-geographical region of their own. Each of the solstices is followed by a rainy season, which causes the West Indian archipelago to be well wooded to the tops of the mountains. The present vegetation is, however, different from the aboriginal. When first discovered by Europeans the whole of Jamaica was almost entirely covered with mahogany trees and Cedrelas; maize was the only crop. The forests, however, soon disappeared on the coasts; the sugar-cane became the principal product of the low districts, and coffee-plantations arose on the hills.

Since the emancipation of the slaves, these crops have been to a considerable extent replaced by pasture land; and even the meadows are being changed by the introduction of foreign grasses.

17. *The Cis-equatorial Region of South America.*

The shores of this region are covered with dense forests, while in the interior of the continent, where the sea-winds have been deprived of moisture by the action of the chains of mountains, extend the great savannahs of Guiana, and the boundless llanos of Venezuela, covered by an extraordinarily rich fauna, and characterised by a sharp contrast of dry and moist seasons. These forests, which clothe especially the shores of the Amazon, are mostly evergreen, with but few Coniferæ, and marked by Passifloraceæ, Piperaceæ, *Phytelephas*, *Tabernæmontana*, and a great variety of palms. The savannahs are grass plains sprinkled but sparingly with trees; in the spring they resemble the northern prairies, splendidly gay with the most brilliant flowers; while in the autumn they produce thinly-sown corn-crops, till the commencement of the rainy season brings again the grass and the flowers. The llanos are grass plains often entirely destitute of trees, sometimes dry deserts, at others flooded by continuous rain.

18. *The Amazon Region.*

The uniformity of a tropical temperature, and the regular increase of moisture, produce on the banks of the Amazon and neighbouring streams a forest-region known as 'Hylæa.' In the main stream the greatest height of the water exceeds the lowest by as much as from 13 to 17 metres; and since the shores are perfectly flat, the forest is flooded every year on both sides of the river to a breadth of several geographical miles. This tract of country is known as 'igapo,' consisting of forests in which the trunks of the trees stand for months in water from 3 to 13 metres deep. Among the more important trees are Mimosas, Lauraceæ, and Ficuses, intermixed with and overtopped by magnificent palms, among which is the Moriche-palm, *Mauritia flexuosa*; there are no woody lianes. Beyond the region of the floods are the Ete- or Guaçu-forests, in which the prevalent forms are the dusky Lauraceæ, with the brazil-nut, *Bertholettia*, covered everywhere by stout lianes. The forests on the Rio Negro differ from those near the Amazon in the rarity of palms and lianes. The natural products of all these forests are unbounded:—brazil-nut, caoutchouc, cocoa, vanilla, sarsaparilla, with valuable woods, vegetable fibres, and medicinal plants in the greatest variety.

19. *The Brazilian Region.*

Along the whole of the south-east coast of Brazil stretches a chain of mountains, the Serra do Mar, rising to an elevation of 7,000 feet, the slopes of which are exposed to the trade-wind, and collect a considerable amount of moisture. This is succeeded in the interior by a broad table-land consisting of argillaceous slate, deprived by the Serra do Mar of the Atlantic moisture, and therefore covered everywhere, except where there is running water or bogs, by savannahs, called in Brazil 'campos.' Here, in the southern summer, the rainy period produces, as if by magic, a vegetation which is dormant during the dry season, the alternation being exhibited especially in the widely distributed savannah-forests, the 'catingas.' The campos are naturally divided into a northern plain, a central table-land, and southern tracts beyond the tropics. In the northerly campos, as in the llanos north of the equator, the savannah-grasses flourish with their loose tufts, and among them rise a few columnar cactus-stems. On the table-land the number of shrubs with coloured flowers increases with the elevation of the ground; and *Melocactus* takes the place of the columnar forms. Both sections possess thickets and forests, but composed of different trees. The almost unmixed groups of *Araucaria brasiliensis* are peculiar to the southern savannahs. To the west the savannahs extend as far as the affluents of the Paraguay and Madeira. Here, as on the coast, we come again to primeval forests, the 'pantanals,' of a tropical luxuriance, which, like the forests of Hylæa, owe their peculiarities to running water. To the south of these the plains of Gran-Chaco, and the woody highland of Paraguay, alternating with open grass-plains, almost entirely fill up the space between the Andes and the southern table-land of Brazil. Here are found the forests of 'algarob,' belonging to the Mimoseæ, and the Brazilian wax-palm, *Copernicia cerifera.*

20. *The Tropical Andæan Region.*

Throughout almost the whole of this region, like the last, there is a natural distinction between a chain of mountains rising almost immediately from the shore of the Pacific, forming a kind of littoral cordilleras, and an eastern series of peaks which slope down to the broad lowlands of South America. In Peru and Bolivia the western chain includes an extensive highland, the Sierra or Puna district; while on the southern tropic both the ridge and the peaks disappear, and give place to the desert of Atakama. The Pacific coast of this entire region is an altogether rainless country, which is only watered in winter by slight mists, the 'garuas;' the Antarctic current of Humboldt which skirts the coasts bringing constantly fresh quantities of cold water, and causing the condensation of the aqueous vapour brought by the sea-winds. Drought prevails therefore not only on the land, but also on the sea, as is shown by the guano-deposits of the Chincha Islands. Only on the shores of the short rivers, or by means of artificial irrigation, can cultivation be carried on in detached spots. Even the higher portions of the coast-range, as well as the Puna district, are treeless, but are covered with an Alpine herbaceous and shrubby vegetation. A richer tropical vegetation is to be met with in the Peruvian Andes only on the eastern slope of the eastern Cordilleras, or in the valleys which intersect the Puna district with deep rocky channels, and lead to the lowlands and the sea. A long rainy season in summer is here a source of inexhaustible fertility ; coffee, the plantain, sugar-cane, and cocoa, are the cultivated crops. While the botanical features of the district at the foot of the Cordilleras and in the deep valleys, merge gradually into those of the Brazilian flora, the upper belt of woods, the Ceja of the Montaña, present some peculiar features, tree-ferns, palms, Guttiferæ, Scitamineæ, and especially the most important of all, the *Cinchona* or Peruvian bark.

21. *The Pampas Region.*

By a Pampas is meant a treeless pasture-land covered with grass ; but in the region of vegetation so designated must be included the whole country extending from the boundary of Brazil, where the regular rainy seasons of the tropical zone cease, across the States of La Plata and Patagonia nearly to the southern extremity of the continent. The true pampas resembles the grass plains on the Missouri; and the thickets and thin woods which occur in the provinces of La Plata lying nearer to the southern limit of the tropic, resemble the chaparals or mesquit-thickets of Texas and New Mexico. The nature of the vegetation is here determined by the distribution of the moisture ; the greater part of the rainfall takes place in the form of sudden thunder-storms, while at other times the air is extremely dry, but with copious dews at night. Long periods of drought intervene, the storms often failing altogether for years. This is the cause of the entire absence or the extreme scantiness of the arborescent vegetation. The climate is not, however, in itself unfavourable to the growth of trees, as is the case with the prairies and the steppes of the Old World. In Uruguay generally the cultivation of trees is possible ; in Buenos Ayres the peach is grown for the sake of its wood.

The Pampas-region may be divided into three zones :—the interior north-western Chanar steppe ; the true Pampas; and the southern plains of Patagonia. The first is not occupied to any great extent by grass, but is chiefly covered by underwood, especially the chanar-shrub, an Acacia known as 'espinillo,' and species of Cactus. At the foot of the Andes it includes some salt lowlands, the Argentine 'salinas,' where the vegetation consists of only a few saline plants. The true Pampas are grass-plains, in which the trees are confined to narrow strips of low woods along the rivers. There are scarcely any native shrubs or herbaceous plants ; but some from the south of Europe have become naturalized ; thistles and fennel have increased to an enormous extent ; *Onopordon acanthium* has entirely displaced the grass over many square miles, and forms impenetrable thickets, exceeding a man's height. Where the grass-steppe ceases, at the Patagonian Colorado and Rio Negro, a low, sparse, thorny, shrubby vegetation begins, growing among loose stones, until at length this also becomes scarce, and the arid ground, parched by the dry air, produces only a few tufts of a hard brown grass. A small Acacia, which is found alone and solitary in the neighbourhood of the Rio Negro, is so remarkable a phenomenon to the natives that it is regarded as sacred.

22. *The Chilian Transition-Region.*

This region, which includes the northern and central provinces of Chile, enjoys a climate similar to that of the Mediterranean ; but the season of active growth is interrupted by longer periods of drought ; for during one-half of the year vegetation appears dead and the land almost barren. Even on the sea-coast there is no great quantity of trees; the foliage of the bushes is to a considerable extent replaced by spines; and the desolate character is intensified by the wildness of the naked mountains untouched by sea-breezes. Tropical forms of plants are nowhere found.

23. *The Antarctic Forest-Region.*

The Antarctic flora may be compared with that of the north of Europe and of the European Alps. As in northern Europe, the equatorial currents of moist air alternate irregularly with the clear sky of the polar currents; and the rainfall is, in consequence, distributed through all the seasons of the year, and vegetation is usually plentifully supplied with moisture. But since this rainfall is associated with a milder winter than in the northern hemisphere, the greater number of the trees preserve their foliage throughout the year. But notwithstanding this uniform temperature, there is, even in southern Chile, where snow and frost are unknown, a distinct period of repose of vegetation during the winter. While even in the last (Chilian transition) region an increase in the vigour of vegetation coincides with the rainy season, the deciduous trees here lose their leaves at the time when the greatest quantity of rain falls and the temperature is also falling.

The Antarctic region may be divided into a northern and a southern zone. Forest prevails everywhere. In the northern zone, which includes also the island of Chiloë, the forest is composed of a great number of trees belonging to different families, including Lauraceæ, Myrtaceæ, Oleaceæ, and even bamboos; lianes and parasites cover the stems and fill up the space, as in the tropical forests, but not with the same abundance of forms. In the southern zone, on the other hand, almost the only trees are beeches; but since the most common deciduous species, *Fagus antarctica*, is accompanied by an evergreen kind, the general aspect of the forests is quite different from that of northern Europe. It is only in the extreme south, where the diminished temperature and the moisture which remains in the ground are favourable to the formation of peat, that the forests yield to open moors. But the vegetation of these moors is peculiar, consisting of a saxifrage and a plant allied to the lilies, associated with cranberries, Ranunculi, and rushes.

24. *Oceanic Islands.*

The native plants of islands often differ considerably from those of the nearest continent ; the aboriginal flora has been preserved in greater purity than elsewhere ; and it is to insular floras of this character that the important theory of the migration of plants owes its origin.

The Azores, Madeira, and the Canaries, an archipelago formed of lava and volcanic rocks, possess a flora altogether independent, but enriched from without, and known as the Atlantic Flora. That of the Azores resembles the Mediterranean flora; evergreen shrubs and forest trees belonging to the Lauraceæ, together with beautiful Ferns, cover the greater part of the islands. Madeira was, at the time of its discovery, completely clothed with wood down to the shore. But the so-called cedar of the island, a timber-tree with a valuable scented wood, disappeared after a great forest-fire. The vegetation has been completely altered by cultivation. Together with the sugar-cane, which has taken the place of the vine—the latter having been almost destroyed by the vine-disease since 1852—the plantain has been generally cultivated ; tropical fruit-trees are abundant ; but there are no palms. Other noteworthy native plants are the dragon-tree *Dracæna*, the luxuriant forests of laurels, the shrubby heaths, magnificent Ferns, and dense underwood, which characterise the district of the thickets above the laurel-woods. The flora of the Canary Islands has an African character in its lower districts; the prevalent forms here are numerous succulent plants, especially Euphorbiaceæ, the date-palm, and tamarisks. These districts are generally arid, especially since the change introduced in consequence of the vine-disease; and the Opuntias, which serve for the nourishment of the cochineal-aphis, have become one of the most important objects of cultivation. The remaining districts, characterised by laurel-woods, thickets, pines, and Genistas, indicate an Atlantic flora, although the evergreen woods have been to a large extent destroyed.

The Cape-de-Verde Islands differ from those already mentioned in their more tropical climate. The rocks and loose stones, uncovered by wood or even by the least stratum of soil, are heated to so high a temperature by the rays of the sun that it is impossible for the aqueous vapour brought by the trade-wind to become condensed; and since there is sometimes no rainy period, the vegetation of the islands is sparse. Four-fifths of the surface is said to be entirely unproductive; the only cultivated plants are a few introduced cocoa-nut and date-palms, coffee-bushes and fruit-trees. The native flora is generally similar to the Atlantic, while the introduced plants indicate the proximity of Africa.

The volcanic island of St. Helena was, at the time of its discovery at the commencement of the sixteenth century, covered with wood, but the young branches were so completely destroyed by introduced herds of goats, which increased with great rapidity, that three centuries later there was a scarcity of wood, when the goats were taken away and trees introduced from all parts of the globe. The climate, refreshed by a steady trade-wind and two rainy seasons, is extraordinarily fertile; but the introduced plants, and especially the European pines, have completely displaced the native flora.

Madagascar, traversed by lofty chains of granite mountains, which slope on both sides to a littoral lowland, marshy or occupied by lagunes, has a seven months' rainy season. The greater part of the island is in consequence covered with moist tropical forests bordered in the interior by elevated grass savannahs. In the south a scanty thorny vegetation prevails. The most remarkable product of the forests is the 'travellers' tree,' *Ravenala*, a plantain, the fan-shaped leaves of which are hollowed out at their point of insertion into a spacious cavity in which water is caught and retained, so that when pricked they give out a refreshing fluid. Here is also found the aquatic *Ouvirandra* or lattice plant, the leaves of which consist almost entirely of a perforated lace-like network. There are also epiphytic Orchids with enormous flowers, tree-ferns, impenetrable lianes, heaths, bamboos, pitcher-plants, *Nepenthes*, and a few palms.

The flora of the Mascarene Islands (Mauritius and Bourbon) is allied to that of Madagascar. That of the Seychelles is distinguished by the double cocoa-nut, *Lodoicea Seychellarum*, with its gigantic fruits.

The Sandwich Islands enjoy a climate resembling that of Jamaica. In Hawaii plantations of the cocoa-nut palm and bread-fruit alternate with sugar-cane fields; and above the cultivated plain a belt of wood surrounds the volcanoes. The commonest native tree, an Acacia known as 'koa,' raises its crown of leaves above a dense thicket of evergreen underwood. The once abundant sandal-wood has already become scarce from the demand for its timber.

The flora of the Feejee Islands approaches nearest to that of the Indian monsoon region. To the summits of their basaltic mountains they are covered with the most luxuriant tropical vegetation. The most important food-plants are the plantain, cocoa-nut palm, bread-fruit, and in the cultivated fields tapioca (*Arum esculentum*), yams, *Tacca*, and batatas.

New Caledonia exhibits in its flora a resemblance to that of Australia. Its woods are destitute of undergrowth;

Myrtaceæ are scattered over its arid grass-plains at wide distances; its stony mountains are barren.

The flora of Norfolk Island, not unlike that of New Zealand, is remarkable for the Norfolk Island pine, *Araucaria excelsa.*

New Zealand is more nearly related in its flora to the forest region of south Chile than to Australia, which lies so much nearer. The evergreen forest, composed of Myrtaceæ, Lauraceæ, and broad-leaved Coniferæ (among them the *Dammara australis*) includes also tree-ferns and arborescent Liliaceæ, and is often rendered impenetrable by dense thickets of lianes. Shrubs and Ferns mixed together clothe the open slopes of the mountains and the dry plains; Ferns are often the sole representatives of the grass of other countries, and clothe boundless stretches of open land; so that some resemblance may be traced, in the abundance of its fern vegetation, between the flora of New Zealand and that of prehistoric times, especially of the vegetation of the Carboniferous formation. Among the Ferns *Pteris esculenta* is noteworthy for supplying food; and of other native products the valuable New Zealand flax, *Phormium tenax*, belonging to the Liliaceæ.

The uninterrupted southern trade-winds impart to the archipelago of the Galapagos Islands an arid climate. Ascending above the lava fields, covered with light dwarf shrubs and Cactaceæ almost destitute of leaves, we find on the mountains a tolerably luxuriant forest-flora, but with no tropical character. More than one-half of the species are endemic (*i.e.* peculiar to the islands); the rest have migrated from the shores of the Isthmus.

Juan Fernandez is densely covered with forests alternating with grassy plains. No considerable immigration of foreign plants has taken place; and the forests are covered with climbers, which, like the trees up which they twine, occur nowhere else on the surface of the earth. Ferns, tree-ferns, and palms prevail.

The Falkland Islands are densely covered with lofty grasses which have extended themselves over immense layers of peat.

The vegetation of the basaltic Kerguelen's Land, like that of the Falkland Islands, consists of a few Grasses intermixed with tufts of an Umbellifer. There are no woody plants. The most interesting species is the 'Kerguelen's land cabbage,' a Crucifer, *Pringlea antiscorbutica* [differing from most of the Cruciferæ of Europe by being chiefly wind-fertilised].

In the extreme southern latitudes south winds laden with snow alternate with northerly currents of air saturated with aqueous vapour, and perpetual white fogs of unparalleled density spread over the surface of the sea. These fogs are formed also on the islands which lie near this zone, almost entirely depriving them of the rays of the sun. Both flora and fauna are extremely scanty. The remarkable difference between the climates of the two polar zones depends on the great excess of water in the extreme southern latitudes, on the consequent cloudy sky, and on the masses of icebergs which break loose in the summer, and, in melting, reduce the temperature of the better part of the year. But in these southern latitudes, where life is now so scanty, there was once a warmer prehistoric epoch ; for, like the extinct forests of Greenland, the evidence of well-preserved fossil stems proves that a luxuriant arborescent vegetation once inhabited Kerguelen's Land.

APPENDIX A

Vaucheria (Fig. 385, p. 254, and pp. 261, 262) may be taken as a type of the class of Algæ known as the Multinucleatæ, the chief characteristic of which is the extraordinary development in size of the single cell, exceeding anything found elsewhere in the vegetable kingdom. This cell, though often greatly branched, is normally unseptated, except that the portions where the reproductive organs—whether sexual or non-sexual—are formed are first cut off by septa, and it often contains a very large number of nuclei. The non-sexual organs of propagation in *Vaucheria* are of two kinds—motionless *resting-spores* or *hypnospores*, and motile *zoospores*. The former are simply terminal portions of particular tubes or branches, which are cut off by a septum, become detached, form within them a new cell by rejuvenescence, and thus develop into a new individual. The zoospores are larger than in other classes of Algæ, and are entirely surrounded by a fringe of vibratile cilia. In the formation of the zoospores the extremity of a branch becomes cut off by a septum, and constitutes a *zoosporangium*, the contents of which develop into a single zoospore. The male and female reproductive organs are known respectively as *antheridia* and *oogonia*, and these, in most species, are found in close proximity on the same filament, though other species are diœcious. The antheridia are the terminal portions of slender branches, and are sometimes straight, but more often have the shape of a horn or hook. The antherozoids escape through a terminal orifice, and are provided with two vibratile cilia, one pointing forwards, the other backwards. The oogonia very frequently bear a resemblance in shape to the head of a bird, and are also cut off by a septum from the rest of the filament. When mature the oogonium opens by an orifice at the 'beak,' through which a colourless drop of mucilage is expelled. The green contents of the oogonium then contract into an *oosphere*, and a number of antherozoids find their way into the oogonium through the terminal orifice and impregnate it by coalescing with it. The *oosperm* thus formed immediately invests itself with a cell-wall of cellulose, and in this condition passes through a period of rest. At the commencement of the next period of vegetation the oosperm germinates, developing itself into a unicellular filament, fixing itself to some other substance by means of a *rhizoid* or root-like organ of attachment. Several species of *Vaucheria* are common on moist ground, flower-pots, &c., often forming green tufts or thick mats covering a considerable area; others grow in brackish or salt water. As the result of injury or abnormal vital conditions, the filament sometimes becomes septated, and is then know as *Gongrosira.*

FERNS and their allies (Filicineæ) are classified, according to the mode of origin of the sporangium, into *eusporangiate* and *leptosporangiate.* In the former, which comprise the Ophioglossaceæ and the Marattiaceæ, the sporangium proceeds from a group of cells, while in the latter, to which class all the other orders of Ferns belong, it originates from a single hemispherical epidermal cell. This divides, by four successive septa, into four parietal cells, and a nearly cubical central cell, the *archespore.* From the former is developed the wall of the sporangium; the archespore again divides into a number of tapetal or *mantle-cells*, which subsequently disappear, and the whole of the space within the wall of the sporangium is then occupied by a fluid substance, from which are formed, by successive bipartitions of the archespore, the mother-cells of the spores, which are most commonly sixteen in number. In each mother-cell two further bipartitions again give rise to the formation of four spores, each of which is usually invested by an inner coat or *endospore* composed principally of cellulose, and an outer brown cuticularised *exospore*, provided with papillæ, ridges, warts, or other elevations. The term 'vessel,' used in the text of this work in describing the tissues of Ferns and other Vascular Cryptogams, is not strictly accurate. Cryptogams very rarely contain true lignified vessels resulting from the coalescence of a number of cells; the structures which take their place, both in Vascular Cryptogams and in Gymnosperms, are *tracheids*—greatly enlarged cells, the walls of which have undergone lignification in a variety of different ways, so as to give them a strong resemblance to true vessels.

In *Fucus* (Figs. 392, 393) the growth in length of the frond takes place by the segmentation of a single well-marked four-sided apical cell. The pigment, which can be extracted from the frond by cold water, and which colours every part of the plant, is known as *phæophyll* or *fucoxanthin*. The fertilisation of the oosphere by the antherozoids always takes place outside the conceptacle, and very commonly on the wet shore between high and low water mark, the position of the mouth or ostiole of a conceptacle being indicated by a drop of orange-red mucilage which oozes from it, carrying with it the oospheres or the antherozoids. In order to secure the elevation of the organs of reproduction above the surface of the water, they are situated either at the extremities of branches or in the neighbourhood of the air-bladders. The oogonia are developed from unbranched hyphæ in the female, or in the lower part of bisexual conceptacles; the antheridia are produced on lateral branches of the hyphæ in the male, or in the upper part of bisexual conceptacles. The olive-brown antherozoids have a pair of cilia of unequal length attached laterally below the beak-like apex.

The development of the asci in *Penicillium* (Fig. 1) has not, at present, been actually traced to any conjugation of sexual organs, though this probably does take place. The ascophorous hyphæ are borne on two lateral branches from the mycelium, which wind once or twice round one another, and of which it is difficult to say that one is male, the other female. The ascophorous hyphæ are at first enveloped in a dense mass of cells constituting a pseudo-parenchymatous structure ; the asci are produced on terminal branches of these hyphæ, and each usually contains eight ascospores.

The formation of spores in the SCHIZOMYCETES (bacteria) is not confined to the series of forms known as *Bacillus*. *Endosporous* multiplication takes place especially when the organism is badly supplied with food-material, or when vegetation is otherwise interrupted. Those forms in which no internal spores are produced are known as *arthrosporous*, reproduction being effected in them by the simple separation of members, which form the starting-point of new growths. With reference to their behaviour towards the external air, the greater number of the various forms of bacteria require a plentiful supply of free oxygen for the purpose of vegetation, and these forms are known as *aerobiotic*, of which *Bacillus subtilis* may be taken as a type. A smaller number, e.g. *Bacillus amylobacter*, are *anaerobiotic*, and these can not only exist, but their growth appears to be promoted by the exclusion of oxygen. A very few forms of bacteria contain chlorophyll ; in a few others the protoplasm is tinged by a soluble red pigment. It cannot be asserted that a nucleus has at present been detected with certainty in any of the Schizomycetes.

APPENDIX B

SUMMARY OF RECENT RESULTS IN STRUCTURAL AND PHYSIOLOGICAL BOTANY.

1. *Structure of the Cell.*

To the living structure of the cell the term *energid* is now frequently applied. An energid may be destitute of a cell-wall (primordial cell), or each energid may be enclosed in its own cell-wall (ordinary cell), or a number of energids may be enclosed in the same cell-wall (multinucleated cell). Neither the cell-wall nor the bodies imbedded in the protoplasm properly belong to the energid. It is probable that the protoplasm of the cell has frequently, if not always, a reticulate structure. The general protoplasm of the cell, as distinct from the nucleus, is known as the *cytoplasm*, its less granular portion as the *hyaloplasm*. It is probable that protoplasmic threads passing through the cell-wall and connecting cell with cell are a very common phenomenon in vegetable tissues. The different elements of the protoplasm display a different behaviour towards staining reagents; the cytoplasm and the greater portion of the nuclei take up the red stains more readily (*erythrophilous*), while the generative nucleus of the pollen-grain displays a greater affinity to blue pigments (*cyanophilous*). The substance of which the nucleus is chiefly composed, *nuclein*, differs somewhat in its properties, and probably also in its chemical composition, from the cytoplasm.

Each of the vacuoles is enclosed in a very delicate contractile membrane, the *tonoplast.*

The various substances imbedded in the cytoplasm are known under the general name of *plastids.* If colourless they are *leucoplastids,* and these are the special seat of the formation of the starch-grains. If coloured they are *chromoplastids* or *chromatophores,* the origin of the various colouring-matters of the cell; those which give birth to the chlorophyll-grains being distinguished by the special term *chloroplastids.* Minute bodies termed *physodes,* endowed with an amœboid motion, are stated by some observers to occur within the protoplasm filaments.

Starch-grains are formed in the chloroplastids or leucoplastids. The theory that they are composed of two distinct substances, farinose and granulose, is now generally abandoned; and the prevalent view is that they are formed by apposition rather than by intussusception. During the spring and summer the amount of starch in the leaves is constantly varying from hour to hour with the light and the temperature; its conversion into a soluble condition, some form of sugar, is rapidly effected by means of a ferment or enzyme known as *diastase,* which is found in large quantities in the leaves. In some plants, especially saprophytes, a form of starch is found which is coloured reddish-brown instead of violet by iodine. In certain plants, especially in the green Algæ, there are found, within the chlorophyll-corpuscles, bodies known as *pyrenoids.* They consist of a colourless homogeneous proteid substance, and are frequently surrounded by starch-grains. They are regarded as a form of reserve food-material.

The part taken by the nucleus in cell-division has been, during late years, the subject of very careful study by many observers. In certain cases we find *direct division* of the original nucleus into two daughter-nuclei; but a far more common phenomenon is *indirect division*, also known as *karyokinesis* or *mitosis*. This process appears to be connected with remarkable bodies of spherical form, a pair of which are associated with each nucleus, known as the *centrospheres*, *astrospheres*, or *directing spheres*. Before division these bodies place themselves one on each side of the nucleus, and appear to govern the direction in which it is to take place. The network of which the nucleus consists now increases in density, and breaks up into fibrils or *chromosomes*, composed of a substance called *chromatin*. The membrane which encloses the nucleus becomes partially absorbed, and the cytoplasm or *kinoplasm* enters the nucleus. This kinoplasm now forms itself into a number of filaments passing from one directing sphere to the other; these together constitute the *nuclear spindle*; while the chromosomes collect in the equatorial plane of the spindle half-way between the two directing spheres, and form the *nuclear disk* or *plate*. The nucleoli have in the meantime disappeared, to be re-formed at a later period. Each of the chromosomes now splits longitudinally, and the nuclear disk breaks up into two halves, one of each pair of the new chromosomes entering into the composition of each of the new disks. The chromosomes which constitute each half of the disk now move towards the corresponding pole, on reaching which each group of chromosomes constitutes a new nucleus; this becomes invested by a nuclear membrane, and the nucleoles reappear. The two daughter-nuclei are now completely formed.

The structure of the cell-wall is by no means so simple as had been previously supposed. In addition to cellulose, it may contain a variety of other substances, even when in a young and growing condition. Among the most abundant of these are *pectic substances*; it is to their degeneration that the formation of mucilage is often due. It is substances of this nature also that form the lining of intercellular spaces that has often been regarded as of a protoplasmic character.

The living cell-wall always contains a certain amount of mineral substances which remain behind after calcination. Among the more frequent of these are silica and salts of lime.

2. *Structure of Tissues and Organs.*

In a considerable number of trees and shrubs, especially those growing in marshy and swampy situations, a peculiar tissue is found known as *aerenchyma*, consisting of thin-walled cells and very large intercellular spaces filled with air. Its function appears to be to facilitate the respiration of the submerged parts.

The statement that the growing point in Flowerless Plants always contains a well-marked apical cell is often made too absolutely; instances occur in which it consists of a small-celled meristem composed of equivalent cells. The presence of a single apical cell is usual in Gymnosperms. The mode of development of vascular tissue from a multicellular growing point is as follows:—The plerome (see p. 57) occupies the central portion of the growing point. This gives rise, in the older part of the stem, to one or more axial cylinders of tissue, the *steles*, in which the vascular tissue is developed. According as the organ contains one or more of these cylinders, it is *monostelic* or *polystelic*. In it early stage the stele is always surrounded by a specially developed sheath of cells, the *endoderm*; its cells frequently contain starch, and it is then known as the *starch-sheath*. When the procambium forms a continuous layer entirely surrounding the stele, it is known as the *pericycle* or *pericambium*. The earliest formed constituents of the embryonic vascular bundles which subsequently constitute respectively the xylem-portion and the phloem-portion, developing into true vessels or *tracheæ*, are termed the *protoxylem* and *protophloem*.

Tyloses result from the hernioid projection of the thin membrane of one cell through an opening in the cell-wall, into the cavity of an adjoining cell. They often attain a large size.

In many plants, especially those growing in arid situations, special organs for the secretion and storing up of water, *hydathodes*, occur. They are always of trichomic origin, and may consist of one or of several cells. Their most common form is that of a capitate hair, consisting of three or more cells, the hydathodic function being performed by the terminal cell. The excretion of water is often provided for by *water-pores* or water-stomata, structures resembling ordinary stomata, except that they have no power of closing. There is not unfrequently a secretion of saccharine fluid in glands or other structures apart from the flower, often in the leaves. Such structures, *extrafloral nectaries*, have for their object the attraction of injurious insects away from the flower. There are various other modes of protection of the flower against creeping insects. The flower-stalk is often covered by prickles or viscid hairs, or a slimy secretion. A more remarkable provision is furnished by some tropical trees and shrubs known as *myrmecophilous*, in which hollow branches or thorns have become the abode of myriads of ants which do not themselves feed on the leaves or flowers, and which drive away the destructive species.

Among the more abundant colouring-matters of petals and coloured leaves are *anthocyan*, *erythrophyll*, and *carotin* ; the first including a large portion of the blue, the two others of the red pigments. One function of erythrophyll in leaves appears to be to absorb the red light-rays and thus to raise the temperature. The presence of a red pigment even in parts of the flower where it can have no possible purpose in attracting insects, as in the stigmas of the anemophilous hazel, is an indication of this function.

While there are mature seeds from which the endosperm has entirely disappeared, others, which are called exalbuminous, still retain one or two layers of endosperm-cells in the form of the so-called *aleurone-layer*.

3. *Embryogeny and Phenomena of Reproduction.*

It would appear from recent observations that when the oosphere of a flowering plant has not been impregnated by a pollen-tube, its function may be taken up by one of the synergidæ or by one of the antipodal cells, which may develop into a fertile oosperm, in some cases apparently parthenogenetically, that is, without actual impregnation.

The description of the development of the sporangium of Ferns (p. 464) applies also in its main outlines to that of the nucellus (sometimes called the macrosporangium) of Angiosperms. It originates from an *archespore*, always of hypodermal origin, generally consisting of a single cell, sometimes of two or three. The archespore sometimes develops directly into the mother-cell of the embryo sac (macrospore); more often a number of sterile cells are first of all cut off from it, forming the *tapetum*, or tapetal layer.

A very remarkable modification of the ordinary mode of impregnation of the ovule, *chalazogamy*, has been described by Treub and others. The pollen-tube neither enters the ovary by the style, nor the ovule through the micropyle, but makes its way through the tissue of the wall of the ovary to the placenta, and enters the ovule in the neighbourhood of the chalaza; the end of the tube now grows towards the micropyle, being frequently cut off from the rest of the tube, and the nucleus passes into the embryo-sac, without, apparently, the latter being actually entered by the pollen-tube, which frequently branches. In *Casuarina*, where this process was first detected, others of the cells which result from the division of the archespore, besides the embryo-sac, contain sexual nuclei, but there are no antipodals. Chalazogamy, as opposed to the ordinary *porogamy*, has also been observed in several genera of the Amentiferæ and allied orders: in *Corylus*, *Carpinus*, *Betula*, *Alnus*, *Ulmus*, and *Juglans*. In the latter genus there is the further peculiarity that there is no differentiated egg-apparatus; a few free nuclei in the embryo-sac appear to perform its function and to be impregnated by the wandering nuclei from pollen-tubes.

In a few plants, especially in some genera of the parasitic Balanophoraceæ and Loranthaceæ, the relative position of the embryonic vesicles and of the antipodals is reversed, the former being placed at the lower, the latter at the upper end of the embryo-sac. To the mode of impregnation involved in this abnormality, Van Tieghem applies the term *basigamous*, in contradistinction to the ordinary *acrogamous* mode.

In the two last-named orders, and in a few others, a very remarkable reduction is exhibited in the structure of the ovule. This is especially the case in the Balanophoraceæ, where the following three types of structure occur :—(1) The ovules are rudimentary and are reduced to a very small number of cells ; (2) the ovules are obsolete, the endosperm mother-cells being produced directly at opposite sides of the ovarian cavity ; there is, therefore, a placenta, but there are no true ovules ; (3) there are neither ovules nor placenta, a single hypodermal endosperm mother-cell being produced in each ovary.

It has been ascertained that in those plants which display normally both sexual and non-sexual modes of multiplication, such as the majority of Algæ, the production of sexual or of non-sexual cells depends largely on external conditions. Thus, in *Hydrodictyon*, a plentiful supply of nutriment tends to the production of non-sexual zoospores, a limited supply to that of male and female cells.

It is not uncommon for the pollen-tube to go through a resting period, which may extend over months, before impregnation takes place. This is especially the case in the Amentiferæ. In some species of oak there is no trace of ovules at the time when the pollen-tube enters the ovary. It is probable that the passage of the pollen-tube through the style and its entrance into the ovary are facilitated by the production of a ferment which has a disintegrating effect on the tissues. In some instances a large terminal pore has been observed in the extremity of the pollen-tube, through which it is possible that the male nucleus may enter the embryo-sac of the ovule.

In some plants a remarkable elevation of temperature takes place at the period when the flower is expanded and fertilisation is taking place. This is especially observable in those orders—such as Araceæ, Palmæ, and Cycadeæ—in which there are a large number of small flowers enclosed in a common spathe ; the elevation may in these cases amount to as much as 11° or 12° C.

4. *Phenomena of Nutrition and Growth.*

Although the statement (p. 168) may still be regarded as correct that plants have no power of absorbing the free nitrogen of the atmosphere through their leaves, recent researches indicate that there is a very remarkable mode in which certain plants do absorb nitrogen through their roots. This is displayed especially by the Leguminosæ, many genera of which—*Lupinus*, *Pisum*, *Trifolium*, and others—are provided, under normal conditions of growth, with *root-tubercles.* These consist of an hypertrophied mass of cellular tissue, the development of which is incited by a fungus or bacterium derived from the soil through the root-hairs. The cells of the tubercle contain abundance of starch and sugar, as well as immense numbers of minute particles endowed with spontaneous motion, known as *bacteroids*, and which are undoubtedly of organic origin. Experiments show that these tubercles contain a larger amount of nitrogenous substances than can be due to the nitrates in the soil (they may even be formed when the soil has been artificially entirely deprived of nitrates) ; and we appear to have here a remarkable instance of the phenomenon of symbiosis (see p. 289). The bacteroids live on the food-materials of the cells of the tubercle, and, at the same time, supply food to the plant by absorbing nitrogen from the atmosphere and forming nitrogenous compounds. Besides the Leguminosæ, similar root-tubercles, with probably similar functions, occur in some genera belonging to other natural orders, *Elæagnus*, *Alnus*, &c. Some authorities attribute this function in all cases to the same organism, which they call *Rhizobium* ; others regard the bacteroids of different species as specifically distinct. The normal conversion of ammonium salts into nitrates in the soil is apparently due to a special class of bacteria, the *Nitrobacteria*, the phenomenon being known as *nitrification.*

Another mode in which certain plants absorb nitrogenous food-material from the soil is by means of *mycorhiza.* This consists of a mass of fungus-mycelium, which either clothes the ultimate ramifications of the root with a thick mantle (*ectotrophic*), or fills up their cell-cavities (*endotrophic* mycorhiza). The former is especially characteristic of the Cupuliferæ and of some Gymnosperms ; the latter occurs in Orchideæ, and in many other plants The fungus carries on a symbiotic existence on its host ; that is, it itself absorbs food-materials from the decaying humus in the soil, which it gives up to its host, flourishing itself on the nutrient nidus thus produced. It produces no reproductive organs ; the ectotrophic form appears to replace the root-hairs.

Many fresh instances of symbiosis have lately been recorded, not only of Fungi, but also of a *Nostoc*-like Alga within the cells of Fern-prothallia or of other Cryptogams ; and even of Algæ with animals.

The effect of the *electric light* on vegetation is to promote the formation of chlorophyll, and at the same time a simpler anatomical structure of the leaves. Alpine plants cultivated under a continuous electric light exhibit points of structure identical with those of Arctic plants.

Electricity, both terrestrial and atmospheric, appears to exercise a favourable influence on the germination of seeds and on the growth of plants.

Many organs, especially leaves and procumbent stems, exhibit a tendency either for the upper surface to grow faster than the under, or the under to grow faster than the upper surface; to the former phenomenon the term *epinasty*, to the latter the term *hyponasty* is applied. All the various modes of the vernation of leaves and the æstivation of petals (see p. 84) are due to the operation of these forces; circinate vernation especially is the result of very strong hyponasty.

In addition to diastase, the important function of which in converting starch into sugar has already been mentioned, there appear to be a large number of *ferments* or *enzymes* in the vegetable kingdom, which destroy the constituents of the cells with which they come into contact, always by a process of hydration. The passage of the pollen-tube down the style and through the ovary, the absorption of food-material by parasitic flowering plants by means of their haustoria, and the destructive effects of parasitic fungi, all appear to be greatly promoted by the action of enzymes.

Living plants, whether herbaceous or woody, exhibit, at all events in cold weather, a higher temperature than that of the surrounding air, either from the absorption of heat or from the chemical processes that go on in them.

5. *Phenomena of Movement.*

The phenomena of *heliotropism* (see p. 207) have received much attention of recent years. Heliotropic irritation may be transmitted from a portion of an organ which is illuminated on one side only to other portions of the same organ, the transmission taking place from the apex towards the base of the organ. The direct irritation is confined to a very small apical region of the organ, or is most strongly displayed there. The region in which the heliotropism is most marked is not that of most rapid growth, the irritability itself not being dependent on growth, though the power of curvature is. The decapitation of seedlings entirely destroys their heliotropism for a time. The majority of stems are positively heliotropic, growing towards the source of light; while roots are negatively heliotropic, growing, as a rule, away from it. Roots, on the other hand, exhibit positive *geotropism*, growing downwards in accordance with gravity; while most stems are more or less negatively geotropic.

Hydrotropism is the tendency of a growing organ to curve towards or away from moisture; the former (positive hydrotropism) is a frequent phenomenon with roots. The tip of the root has, in many plants, a tendency, when placed in contact with running water, to bend itself directly or obliquely against the current. This is known as *rheotropism*. By *aerotropism* is understood the attractive or repulsive force exerted on living organisms by the oxygen of the atmosphere. It is displayed especially by bacteria.

By *chemiotropism* or *chemiotaxis* is meant the influence exerted on the movements of organisms or parts of organisms by the chemical composition of the substance with which they are in contact; and this influence may be either attractive (positive) or repulsive (negative); the quality of the chemiotropism depending on the concentration of the chemical substance. The motile antherozoids of Cryptogams (Ferns, Mosses, Algæ) are attracted in this way either to the open mouth of the oogonium or to the naked oosphere; the growth of the pollen-tube is promoted by the attractive force of substances which it finds in the stigma, the style-canal, the ovary, and the micropyle of the ovule; the entrance of the hyphæ of parasitic fungi into the tissues of the host is assisted in the same way; and a similar phenomenon is displayed by the plasmodia and the myxamœbæ of the Myxomycetes. The chemical substances most active in this way are cane-sugar and salts of phosphoric and malic acids. Hybridisation is apparently hindered by the fact that the antherozoid or pollen-tube of each species finds its most attractive compound only in the female organ of the same species.

Nyctitropic movements, or those connected with the *sleep of plants*, are exhibited by the leaves and petals of many species, resulting in a difference between their diurnal and nocturnal positions. As a general rule both petals and leaves occupy a more or less horizontal position in the day-time, with their upper and under surfaces facing the sky and the earth, while at night they stand erect or droop vertically. The erect position at night is advantageous in diminishing loss of heat from excessive radiation; while the horizontal diurnal position exposes the leaf most fully to the action of light, and renders the petals most conspicuous and most convenient for visiting insects. Of this character are the changes in position of the leaves of *compass-plants* (*Silphium laciniatum* and others). The movements of fruit-stalks by which the seed-vessel is brought into the most favourable position for the dissemination of the seeds are termed *carpotropic*.

The causes of the *curvature of tendrils* and of climbing stems and petioles form a very complicated problem. The main factor is the irritability of growing members to mechanical stimulation, causing them to curve round the object with which they have come into contact. Fresh portions of the coiling organ are thus brought into contact with the support, and these again curve from the mechanical irritation. The coiling of a free tendril or of the free portion of a tendril is a function acquired by heredity. The prime cause of the movements of tendrils is probably the irritability of the protoplasm on the concave side, causing contraction of this side; while the movements of leaves and petioles and of the tentacles of *Drosera* appear to originate from cells on the convex side. The protoplasm of the concave side (in tendrils) is more granular, and occupies a larger proportion of the cell-cavity, than on the convex side. The region of maximum growth lies between the middle and the tip of the tendril, and does not coincide with the region of greatest irritability.

6. *Structure of Flowerless Plants.*

The structure of the *Cyanophyceæ* or Phycochromaceæ, those Protophyta the cell-contents of which are coloured by a blue-green pigment (*cyanophycin*), has been subjected to many careful investigations. Whether the central portion of the cell-contents is so far differentiated from the peripheral portion as to be correctly termed a nucleus is still a subject of controversy. It is of looser structure and not reticulate, and it possesses no true nuclear membrane, nor does it contain nucleoli. It should probably be regarded as a rudimentary nucleus. The cyanophycin is frequently present in the form of distinct granules.

The remarkable movements of the *Oscillatoriaceæ*, from which they derive their name, are of two kinds—a gliding movement along the surface of the water, and an oscillating movement in one plane. Their purpose is probably to bring the filaments within the reach of fresh food-supplies.

The *Diatomaceæ* are now generally regarded as having a greater affinity with the Cyanophyceæ than with the Conjugatæ among Algæ. The structure of the siliceous diatom-shell has been one of the most fertile subjects of microscopic observation, though many points still remain undecided. In a large number of diatoms, especially in those found in deep seas, the siliceous coating is beautifully areolated, and the nature of this areolation has been much controverted. The most trustworthy observations indicate that it is due to perforations in the silex. The overlapping edge of one of the two valves over the other is known as the *girdle* or *hoop*, and this may be simple or there may be several girdles. In many species the central space in each valve shows, at the middle and at each end, a strongly refractive bulge or *nodule*, and the nodules are frequently connected with one another by a more or less prominent rib—the *raphe*, the presence or absence of which is used in the primary classification of the families. The line bounding the two valves is the *suture*.

The ordinary mode of multiplication of diatoms is by simple fission ; according to some observers sporulation, or the formation of internal spores, also occurs frequently. The formation of auxospores has been observed in many species. There are five different kinds—viz. : (1) rejuvenescence of a single cell, accompanied by an increase in size ; (2) two daughter-cells may be produced from the protoplasm of a mother-cell, the auxospores arising from these ; (3) two cells lying side by side may cast off their old valves, and each grow into an auxospore without any previous fusion, or any visible interchange of contents ; (4) a true conjugation may take place, the protoplasmic contents of the two cells fusing together, and the result developing into an auxospore ; (5) before conjugation the protoplasm of each of the two cells may divide beforehand, and two auxospores be formed by the fusion of a daughter-cell from each mother-cell with the daughter-cell of the other one lying opposite to it.

The cause of the movements of diatoms has been a subject of much speculation. The view now generally adopted is as follows. The raphe is, in many genera, a hollow canal which is in open communication with the interior of the cell, and is clothed with protoplasm. From this protoplasm fine threads pass through delicate pores in the membrane, and it is by means of the oscillation of these threads that the diatom performs its creeping movement. The threads are wanting at the poles. The comparatively rapid free swimming motion by jerks of some species is probably due to some other cause. The filaments are, according to one authority, of a granular nature.

The so-called 'fungus-cellulose' of which the cell-wall of fungi is composed is a substance of complicated structure, often containing no true cellulose. Among its constituents are ‘chitin’ and ‘callose.’ The mycelium of parasitic fungi can generally be clearly distinguished by its chemical reaction from the tissue which it penetrates.

The mode of reproduction in the Ascomycetes and the Uredineæ is still not fully known in some points. While in some genera of Ascomycetes the ascus is undoubtedly the result of a true sexual process, in others it appears to be produced parthenogenetically. In the Uredineæ a fusion has been observed of the two nuclei present in the teleutospores ; but there is reason to believe that this is not of the nature of a true sexual conjugation. A similar fusion of nuclei has been observed in the Ustilagineæ.

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